MICA

ITS HISTORY
PRODUCTION &
UTILISATION.

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A Picture Painted on a Sheet of Mica from India.

MICA

Its History, Production, and Utilisation

BY

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INTRODUCTORY.

At one time the name "Mica" was employed for various minerals which glittered and possessed the property of cleavage, without any sharp distinction being drawn between the several kinds. As the science of mineralogy advanced, however, more and more species came to be distinguished, so that to-day one speaks no longer simply of Mica, but of a Mica group. According to Naumann, this group is comprised of ten species, of which each includes a number of varieties. Hintze gives the following :

Summary of the Mica Group.

1. Ferromagnesia Mica : Biotite (Meroxene, Anomite, Lepidomelane, *Phlogopite*).
2. Ferrolithia Mica : Zinnwaldite (including "Raven-mica," Kryophyllite, and Polylithionite).
3. Alkali-Mica,
   (*a*) Lepidolite : Lithium Mica.
   (*b*) Muscovite : Potassium Mica.
   (*c*) Paragonite : Sodium Mica.
4. Chalk or Lime Mica : Margarite.

According to this classification, which will be taken as the basis for the following notes, phlogopite is classified with biotite, with which, in fact, it has a great similarity.

We cannot here undertake to deal with all the micas, but shall rather concern ourselves only with those which have great technical importance, and are therefore extensively mined. From the earliest times these have been the muscovite, or potassium-mica, and the phlogopite species. The latter is a magnesium mica which, on account of its colour, is also called bernstein or amber-mica. Both differ in their geological occurrence, in their chemical composition, and in some degree also in their properties.

HISTORICAL.

It is not surprising that a mineral of such striking characteristics should from earliest times have attracted the attention of mankind. In prehistoric times it was already known to the American Indians, and was employed by them for many purposes. On account of its iridescence it was used for purposes of decoration, while its property of reflecting light resulted in its being used as a mirror. Considerable quantities of mica were buried with the dead, as shown by the remains unearthed in the district of Ohio, U.S.A., and we even know the method employed by these very early inhabitants of America in obtaining it. By means of the fire-drill, a great fire was started close up against the rock containing the desired pieces of mica, and when the stone was red-hot, the fire was withdrawn and the rock cooled by pouring water over it. The sudden change of temperature split the rock, and so enabled the embedded mica to be extracted without the aid of explosives. Tools have also been found in the prehistoric mines : stone hammers for working the broken pieces of rock, and on the shores of the "Upper Lake" even copper implements.

In India, also, the use of mica was soon discovered, and several mines there have been working for centuries. The glittering flakes were employed for all kinds of decoration, and larger pieces were used as lantern panes. The most important markets were Patna and Delhi.

The mineral was similarly employed in Greece and Rome. The ancient lamps, consisting generally of

a clay oil-vessel with a wick extending out of its neck, were easily extinguished by a draught, and, in the absence of matches, were not so readily ignited again. Lanterns, therefore, were always used out of doors, and, on account of the absence of public street-lighting, were a necessity in every household. The transparent, or rather translucent, cover was made of horn, bladder, oiled linen or mica, and later glass. Up to the time when it was found possible to manufacture glass plates of a size large enough for lantern panes, mica must have been the best, although the dearest, substitute. Fig. 1 shows a bronze Roman lamp from Herculaneum. The lower portion consists of an oil vessel *B*, with an opening on top through which the wick projects. The cup-shaped top *C* has several holes *D* in it to afford a passage for air, and is fastened by a chain to the upper cross-piece *A* of the handle. Access to the inside is gained by lifting this portion of the handle.

Mica has served as a substitute for glass in other ways. Thus it is recorded by Pliny that the windows of the living rooms, baths, porticos, hot-houses * and carrying (Sedan) chairs were of mica. Seneca also mentions "specularia," or window panes probably of mica. Even bee-hives were constructed of mica so that the insects could be more readily observed. On festive occasions, the arena was sprinkled with waste mica flakes to obtain a glistening effect. Pliny makes mention of "lapis specularis," or "mirror stone," and discourses on its properties. His description, however, often applies better to gypsum, for which mineral he, in another place, uses the word "gypsum," and refers to it as something different to "lapis specularis." This confusion by Pliny of the two minerals, however, is nothing to be surprised at, as they have much in common; and to-day even, the name of "Marienglas," or St. Mary's glass, is applied both to gypsum and to mica. His remarks, however, can be assumed to apply generally to mica.

* *Cf.* also Martial Epigr. VIII, 14.

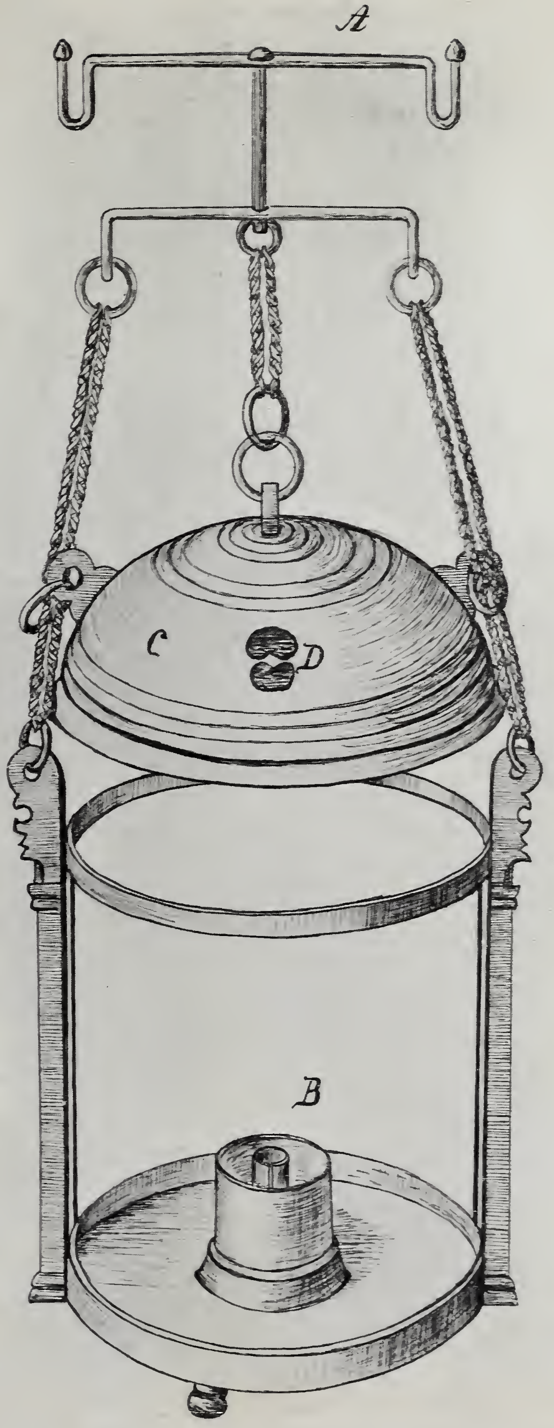

Fig. 1.—Roman Bronze Lamp from Herculaneum.

He has the following to relate of "lapis specularia." It was obtained chiefly from Spain, from the neighbourhood of the city of Segobriga, which probably corresponds with the present city of Priego in Andalusia. Quarries of considerable size were established there, and the pieces dug out reached in some instances a length of five Roman feet (nearly one and a half metres). Most were white in colour, but some were black. According to Pliny the white pieces were best able to withstand frost and the heat of the sun, and, unless mechanically damaged, were very durable. Their property of being easily split up into thin flakes is also mentioned by him. Besides Spain, the following places of origin are given: Cyprus, Cappadocia, Sicily, Africa; and in Italy, Bologna only. The Spanish stone was admitted to be by far the best. The Cappadocian stone was found in large pieces, but was more opaque. The stone from Bologna was the poorest, being small and flaky.

Corresponding with the ancient Roman name of "lapis specularis" was the Greek name τὸ διαφανές "the transparent," which shows that the property of mica of letting light through was noticed by the Greeks to be its special characteristic.

The writers of the middle ages, when discoursing on mica, repeatedly confused this mineral with gypsum, as did Pliny before them. On the other hand, there were several names for mica, as the different varieties were held to be different kinds.

Agricola, one of the earliest of the mediæval mineralogists, writes of lapis specularis, διαφανές, magnetis, ammochrysos, "cat's gold," "cat's silver," "Our Lady's Ice-spar," or simply "ice" (glacies), and also mentions the name *mica*, obviously derived from the Latin "micare," to shimmer or sparkle. This name was later introduced into the French, English, Italian, Spanish, and other languages, and is now the most generally used term. Agricola mentions the same places of origin as does Pliny, but adds to them some in Germany, such as Hildesheim and Nordhausen. He refers to the resistance of the mineral to the effects of heat and cold, but

adds that it cannot withstand rain. Curiously enough, however, he states, in spite of this, that it is employed on account of its transparency for windows, and gives as examples the Church of Coswig and the Cathedral of Merseburg. Its healing properties are also said to be excellent. Powdered and mixed with wine it is recommended as a cure for dysentery, and the application of powdered burnt mica to ulcers is said to cause new flesh to form rapidly. Mica was also known to Agricola as a constituent of rocks; thus, he writes, "it glitters in rock, in marble, and in sand, and is so embedded that it cannot be separated from them." Mica does not appear in marble, however, and what Agricola noticed were evidently the shining surfaces of the small crystals of which marble is composed. The name "cat's silver" refers to the metallic appearance of some pieces of mica; thus, he writes, "it is so like silver that children and others, ignorant of the properties of metals, mistake it for such," and "many call it a metal on account of its glitter, and others name it cat's silver (nominant vocabulo ex fele et argento composito)."

That mica contained no real silver, and, indeed, was not a metal at all, was known to Paracelsus. In the latter's denunciation of the false doctors, he compared their pseudo-science with the deceiving glitter of "cat's silver, which lies in the sand glittering as if it were gold or silver" and yet is of no value. The name "Our Lady's Ice" was also known to him; thus, "Sals scissum, entali, alumen scissum, idem, unser Frawen Eyss."

It is not generally known that Konrad Gesner, the great ntauralist, left behind him not only works on plants and animals, but also a comprehensive book on minerals. He was acquainted with the hexagonal outline of the completely developed mica crystal, and also gives approximately the same list of characteristics as Agricola, making special mention of the pronounced cleavage. Halle is included in the list of places where the mineral is found. The inhabitants of Halle, he says, call the stone "salem fatuum," or "worthless salt," obviously comparing

it with the common salt found in that neighbourhood. The "worthless" probably referred to the absence of taste in consequence of the insolubility of mica. Plates are made of an iron-coloured "magnetis," while Ammochrysos, or "gold dust," is used by writers instead of sand for erasing purposes. Plates of a suitable size are used as mirrors, and in Thuringen and Saxony round panes are made from "specularis" and inserted in the windows. Finally, Gesner mentions a medical application of mica; it is valuable, he writes, in cases of lunacy and epilepsy ("ad lunaticum et spumantem morbum").

Böetius de Boot includes "lapis specularis" and the selenites in one chapter under the heading of "Our Lady's Ice." He does not give the numerous bewildering names used by other writers, and so makes an important step forward in the nomenclature. "Muskowia," in Russia, is mentioned as a source of the mineral, and it is from this place that Muscovite, or potassium mica, has received its name. Fire, says Böetius, changes mica into a white powder, used by women to whiten the face and to dispel wrinkles. The mistaken idea that mica is converted to gypsum by burning, was originated by Pliny and repeated by Böetius. Amongst its other uses, Böetius mentions its application to lanterns and windows.

Wallerius, in 1747, first distinguished several varieties of mica. He mentions a "variatio alba, flava, rubra, viridis, nigra, squamosa, radians, fluctuans, hemisphaerica (white, yellow, red, green, black, muddy, streaky, wavy and hemispherical). The German word "Glimmer" was laid down as the correct German scientific name by Werner, the father of modern Mineralogy, the word being derived from "glimmern," meaning to glitter, and therefore analogous to "mica," both of which terms clearly express the most striking characteristic of the mineral.

Some information concerning the production and applications of mica at the end of the eighteenth century is given in an encyclopædia by Johann Beckmann, published in Göttingen in 1796. At that

time, practically all the mica used in Germany came from Siberia, particularly from the banks of the rivers Witim, Mama, Aldan, and Olekma, tributaries of the river Lena, where an excellent class of mica was found in large quantities. Russia itself was the largest consumer. Both in Siberia and European Russia, transparent sheets of mica were fixed in metal frames and employed as window panes, while

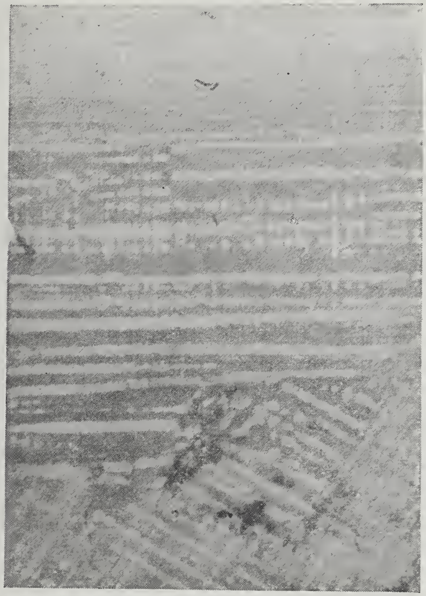

Fig. 2.—Streaked Mica from Brazil.

(*Photo by Oliver G. Irons, London.*)

it was still in use at this time for lanterns. In St. Petersburg, also, at this time, it was customary to place pieces of coloured mica in front of candles or other lights used for decorative purposes to obtain the effect of a coloured light. Opaque, black mica was employed by Russian art workers for making little caskets for playing-counters and ladies' dressing tables.

In Germany, the use of mica was far less extensive. A small quantity was employed by the toymakers of Nuremberg to serve instead of glass. Carpets and drapery sprinkled with mica were fashionable at that time, and the waste flakes of mica were employed for that purpose, as is the case to-day. Mica strips were used for mounting microscopical objects, and also for sealing bottles containing zoological objects preserved in spirit.

The name "Marienglas," or "Frauenglas" (St. Mary's glass), is explained by Beckmann as being derived from the almost universal custom of sprinkling pictures and images of the Virgin and other religious groups with flakes of mica. The Nuns of Reichenstein, in Saxony, are recorded to have sprinkled the "Agnus Dei" bought from the mountain shepherds in the same way with coloured flakes of mica. That a similar custom prevailed in France at one time is shown by the name "Pierre à Jésus," which was a common one in French monasteries.

It is interesting to note that an application of mica in a somewhat similar connection is still common in Russia, where the pictures of the Madonna are covered with a very thin sheet of mica so that they shall not be damaged by the people when, as is the custom, they kiss them.

The mineral was still at this time obtained in a primitive manner. "Generally," says Beckmann, "some forty persons form a society or company to bear the cost of the necessary tools, etc., and also divide the work of obtaining and preparing the mineral amongst themselves in a definite agreed manner. Some seek the faults where the mica is exposed, others break up the rock, while others clean and split up the pieces of mica extracted. Some act as smiths and care for the tools, while others prepare the food. One is always selected as arbitrator and overseer. When seeking for mica, the shrubs, moss, etc., which hide the mountain slopes are burnt away so that the extruding pieces of mica can be seen, and when an upcrop is discovered a hut is built for the workers, who use only hammers,

chisels, levers, and shovels. Some seams yield twenty or more pud (one pud equals about 40 lbs.) of mica, and there may be as many as one hundred seams in a single pocket, or only a few. The pits are commonly twenty fathoms long, by five wide, and two fathoms deep. Directly a quarry is exhausted another is opened up elsewhere."

During the next decades the consumption of mica as a substitute for glass for window-panes gradually fell off in consequence of the steady increase in the number of glass-works. These were necessarily established close to the towns, on account of the difficulty in transporting glass by the available means. New applications gradually developed, however, which absorbed considerable quantities of mica, and were the foundation of the present mica industry.

At this time, the continuously burning stove was developed in America, and, in 1870, or somewhat later, introduced into Germany. To enable the fire to be observed and the stove to be conveniently regulated, it became customary to insert a number of small mica windows in the stove door. On account of the large number of such stoves constructed annually in Germany, the consumption of mica for this purpose is very considerable.

About the same time as the above, the fan-tail burner of the gas-lighting industry was superseded by the Argand burner, and then later, in the 'eighties, by the Auer incandescent burner. In both the latter, and in particular in the case of the incandescent gas lamp, the cylinder enclosing the flame is subjected to rather a high temperature, and must be capable of withstanding rapid alternations of heat and cold on lighting and extinguishing respectively. Before the refractory Jena glass was developed, mica chimneys were the only possible solution, and even to-day have not been entirely displaced.

Of greatest importance, however, was the progress in the construction of high-voltage electrical machinery, which, since its universal development, has increased the production of mica many times over. Mica is an indispensable material in electrical

constructional work, and of such excellent properties that it is most improbable that it will ever be replaced by any other natural or artificial material. It is in this sphere that mica holds its own, and the history of heavy electrical work may be said to be the history of the modern mica industry.

Whereas, in Beckmann's time, Siberia supplied the whole of Germany, and, indeed, Europe with mica, this was quite out of the question after the above tremendous increase in consumption. The increased demand led to the discovery and exploitation of many new mines in America, which were worked on improved methods and produced a material the value of which in the 'seventies was considerably better than to-day.

In 1868, mica was discovered in North Carolina, and in the following years there arose a regular mica fever, similar to the gold fever which had raged in California. People came from all quarters of the globe to try their luck, and sought, quarried, and mined in every direction. This lasted for a decade when the market price fell rapidly with the entrance of India into the field in 1884, and Canada two years later.

Mica had long been produced as an unwelcome bye-product in the phosphate mines in Canada, and was often thrown away. But about 1890, that is, on the establishment of the electrical industry in the United States, a Canadian mica industry was brought into being, and has developed an enormous output, especially to the United States.

Of the Indian sources, at first only Bengal supplied large quantities for export, but here also new fields were discovered. Since 1897 Madras, and since 1905 Rajputana have developed a production which far exceeds the whole export from Canada.

PHYSICAL PROPERTIES.

Mica occurs principally in plates without any regular shape, and varying in size from little scales to plates of considerable dimensions. Remarkably large crystals are obtained from the Lacey Mine, near Sydenham, Ontario. Colles records having seen there pieces of three to four feet in diameter, and one of over 7 feet in length. Another crystal from this mine had a weight of between 30,000 and 40,000 lbs. R. W. Ellis reports in the "Bulletin on Mica" of a plate which was over 9 feet long and from 4 to 6 feet wide. The average thickness of the plates found in Canada is given by Cirkel as four to six inches. Crystals of considerable size have also been found in the recently opened mines in German East Africa. The largest had a length of 88 cm., a width of 78 cm., and a thickness of 15 to 25 cm. But all earlier records were broken by the finding of a crystal in the Inikurti mine in India which measured ten feet over the cleavage surface and 15 feet over the leaves. It is by far the largest which has ever been found in India, and probably the largest ever found in any country.

Most of the plates found in the mines are irregularly constituted in some way, being either nitched, folded, twisted, or intergrown one in another. A large number contain various impurities, and these imperfections account for the small percentage of mica pieces which are suitable for commercial purposes.

Crystalline Form.

Perfect crystals, that is, crystals which have all their surfaces completely developed, are rare, and particularly good specimens which are suitable for optical experiments, or, on account of their perfect surfaces, are adapted to exact angular measurements, are even exceptional. For this reason, there long existed an uncertainty as to the character of the mica crystal. It often appears to be a six-sided regular prism (Fig. 3), and consequently the mica crystal was classified in the hexagonal system until exact optical measurements by Hintze and Tschermak gave a proof that all micas belong to the monocyclic system, although they may approximate to a hexagonal symmetry.

If a mica crystal is treated with a solution of fluorspar in sulphuric acid, it is attacked by the hydrofluoric acid produced, and on interrupting the action at the correct moment curious figures are found to be etched into the surface. These figures correspond in symmetry with the whole crystal, and important conclusions may be drawn from them. Fig. 7 illustrates such "etch-figures" on a cleavage surface of Muscovite. It is readily found that there is only one line which divides the figure symmetrically. The crystal has therefore only one symmetrical plane at right angles to the etched surface, instead of six as would be the case if it belonged to the hexagonal system—a further proof of its monocyclic character.

The crystal forms of muscovite and of phlogopite are very similar, both resembling hexagonal plates or low prisms (Figs. 3–6). Occasionally the crystal has a pyramidal form, as in the case of the muscovite crystals from Lake Ilmen. The angle between the two surfaces marked *m* in Fig. 4 of the normal mica crystal is 120° 47′, differing thus only slightly from the angle of 120° of the hexagonal crystal, and thus accounting for the apparent hexagonal shape.

Occasionally one meets with twin-formations, that is, crystal forms produced by the intergrowth of two crystals according to fixed laws. Generally the two

BIOTITE CRYSTALS (3—6).

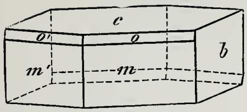

Fig. 3.—Single Individual.

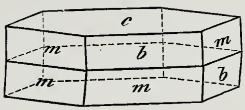

Fig. 4.—Twin, with individual crystals lying one over the other.

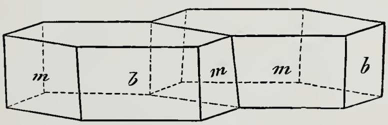

Fig. 5.—Twin, with individuals lying side by side.

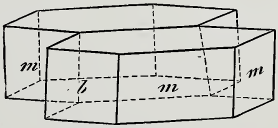

Fig 6.—Twin, with individuals lying side by side.

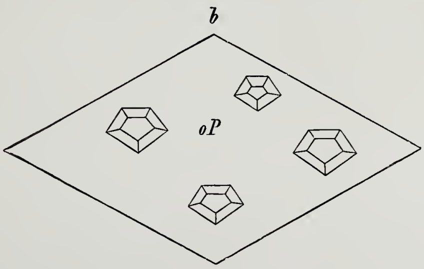

Fig. 7.—Etch-Figures on Muscovite.

(*All from "Mineralogy," by Naumann and Zirkel.*)

individuals lie one on top of the other (Fig. 4), but sometimes they lie side by side (Figs. 5 and 6). The axes of two crystals grown one over the other, as in Fig. 4, are generally at an angle of 120°.

Foreign bodies are very often found embedded in the crystals; for example, in muscovite, scales of feldspar, or, rarer, small crystals of beryl, needles of tourmaline, crystals of quartz, feldspar, garnet or zirkon. In phlogopite, one finds calcite, apatite, feldspar, and quartz. Brown or red layers of iron-oxide occur in both. These impurities can, when they are present to a large degree, render the mica unfit for use, as they are mostly conductors of electricity. They occur generally in the form of dendritic asterisms. Often, they take the form of lines or streaks lying in three directions and cutting each other at 60°, parallel to the percussion lines (see below).

Of particular interest are the cohesive properties of the mica crystal. Practically all kinds of mica exhibit a pronounced cleavage parallel to the plane *c* in Fig. 3. This is so perfect, more so than in any other mineral, that one can obtain flakes of 0·006 mm. only in thickness. The cleavage is most perfect in the harder varieties. It is less in the case of amber mica than with alkali mica. The thinnest flakes that can be obtained by successive splitting of amber mica are about twice as thick as those obtained from hard muscovite. Mica crystals exhibit cleavage also, but to a smaller degree, in other directions at right angles to *c*.

If a needle is set on a plate of mica and is driven slightly into it by a gentle but sharp blow with a small hammer, a remarkable figure is produced consisting of fractures having the form of a six, or sometimes a three-rayed star; this is the so-called percussion figure first observed by Reusch. Of particular importance is the fact that the resultant three lines always run parallel to the edges which the bounding surfaces of the crystal make with the base. This gives a ready means of bringing out the crystal form of completely shapeless pieces of mica.

The discovery of the percussion figure has been of

great value in researches into the physical and, more particularly, the optical properties of the various kinds of mica. It is not, however, always easy to produce at once a good percussion figure. The mica sheet for the purpose must not be too thin, nor, more important still, too thick. The blow of the

Fig. 8.—Percussion Figure.

(Enlarged about 25 times.)

hammer can easily produce a large hole in the flake if too heavy. M. Bauer recommends the use of a base of thick glass on which is gummed a thin sheet of hard rubber. In any case, the base should be quite smooth and fairly elastic. We have ourselves obtained quite good figures by letting an ordinary penholder with nib fall point downwards on the

mica from a height of about 5 cm. As a base we used a smooth piece of cardboard about 5 mm. thick.

If the percussion figure experiment is modified, by using a blunt instrument with rounded end instead of a needle, which is merely pressed hard on the mica plate instead of a blow being given, other lines of fracture will be produced which halve the angles of the percussion figure. These are called pressure lines, and the whole the pressure figure. The pressure lines do not exactly follow the regular arrangement of the percussion figure, but generally consist of only a three-rayed star. Sometimes only one or two of the lines appear. How readily such pressure lines are formed can be demonstrated by squeezing a sheet of mica perpendicularly between the fingers. A system of pressure lines is almost invariably produced in this way, though not always a regular one. Plates which have been subjected to blows and pressure often exhibit unintentionally produced pressure rays of great beauty. Freshly mined mica sheets also show the effects of pressure. The feathery streaks sometimes seen can be traced to the effect of pressure produced by rock movements. These pressure and percussion figures are found in all kinds of mica.

Optical Properties.

The optical characteristics of the mica crystal are particularly difficult to describe in a popular manner. We will in the following paragraphs only describe some of the more remarkable properties. If a clear crystal of Iceland-spar is laid on some printed matter, the letters looked at through the crystal appear in duplicate. This is a result of the well-known optical property of calcite called "double refraction." There are many other double refracting minerals, but they do not exhibit this characteristic to such a pronounced degree. Among these is mica. In every crystal exhibiting double refraction there are either one or two directions in which this double refraction does not occur. This direction is called the "optical

axis," and one distinguishes between single optical axis crystals and double optical axis crystals. Mica belongs to the latter class. The plane formed by the two axes is called the "axial plane," and this direction is of considerable value in determining the nature of a crystal. There are some micas in which this plane is at right angles to the plane of symmetry, and others in which it is parallel to it. The latter are called "micas of the second order," while the former are known as "micas of the first order." Muscovite is a mica of the first order, phlogopite of the second order. It is, therefore, possible to distinguish between muscovite and phlogopite on a purely optical basis.

The angle enclosed by the two optical axes is known as the axial angle. This angle varies considerably with different kinds of mica, the values appearing to have some relation to the chemical composition. This value is never constant for even the same variety of mica, and Tschermak has found different angles even for different laminæ of the same phlogopite crystal. The angle is also dependent upon the temperature of the crystal. Thus, for example, Des Cloizeau, working with red light through a crystal of biotite, observed the following :—

Origin of crystal	Colour.	Temperature.	Axial angle.
Monte Somma ..	Green	17° C. 171° C.	12° 3′ 11° 5′
Canada	Light	17° C. 171° C.	15° 37′ 14° 46′
Siberia	Greenish-brown	17° C. 171° C.	19° 29′ 17° 28′
India	Dark-brown	17° C. 181° C.	22° 35′ 22° 26′

The axial angle of muscovite varies between 40° and 70°. With phlogopite it is considerably less: Tschermak found values for red light between 0° and 17° 25′. The following table gives the results of a number of determinations for micas of different origin :—

MUSCOVITE

Origin.	Axial angle.	Observer.
Bengal	69° 12′	Tschermak.
Tyrol	60° 38′	,,
New Hampshire	67° 30′	Silliman.
Quarry Hill	67°	,,
St. Gothard ...	60°	Sénarmont.
Fossum	66°	,,
Aschaffenburg	64° 48′	Bauer.
Fichtelgebirge	66° 36′	,,
Bavarian Forests	73°	,,

BIOTITE

Origin.	Axial angle.	Observer.
Zillertal	0°	Grailich.
Vesuvius	1°	,,
Lake Baikal	5°	,,
New York State	14°	Silliman.
,, ,, ...	15°	,,
Upper Ottawa	17° 30′ – 18°	,,

The above results show a distinct difference between phlogopite and muscovite, in spite of the considerable variations in the value of the axial angle for the same mineral.

A peculiar optical property exhibited by many pieces of mica is that of asterism. If one holds before a source of light in a dark room a piece of paper which has had a hole made through it with a needle, allowing a ray of light to come through, and looks at this brightly illuminated opening through a suitable piece of mica, one sees at the point of light a more or less regular six-rayed star, the rays of which are at 60° to one another. If the mica sheet is turned about an axis at right angles to its surface, the star is turned round with it, the rays on the plate retaining the same arrangement. A comparison with the percussion figure shows that the rays of the star lie parallel to the percussion lines.

By careful observation a second faint star can be seen between the lines of the brighter star, the rays of which halve its angles. The rays of this second star are, therefore, inclined at 30° to the percussion lines and run parallel with those of the pressure figure. The brighter star is called also the primary or principal star, and its fainter companion the secondary or auxiliary star. The production of this

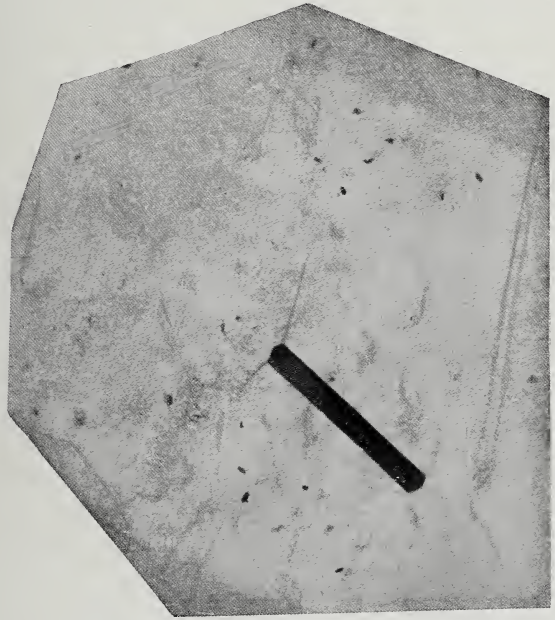

Fig. 9.—Mica Crystal from India with Tourmaline Inclusion.
(Photo by Oliver G. Irons, London.)

effect has been investigated by several experimenters. The cause of this remarkable effect is doubtless the presence of numerous small inclusions in the mica plate, as in the case of several other minerals, such as certain sapphires and cat's-eyes. Under the microscope innumerable fine lines parallel to the cleavage plane of the crystal can be seen. Most of these lie in three directions at angles of 60° with

one another, at right angles to the percussion line, and produce the principal star. A smaller number of needle-shaped structures lie in three directions at right angles to the above inclusions which produce the primary star. These structures are the cause of the secondary star, which is weaker than the principal star because the number of inclusions producing it is smaller (Tschermak). In many cases it has not yet been determined exactly of what nature these included crystal needles are. According to Sandberger they are rutile needles, while Rosenbuch considers them to be fine crystals of tourmaline.

An optical property not so often observed is that called "pleochroism," that remarkable colour effect produced by the unequal absorption of light in the principal directions of doubly refracting crystals. There is no sign of this with ordinary mica sheets, crystals with particularly good development of the principal surfaces being required to exhibit it. Suitable specimens when looked at in the direction of the cleavage plane show a different colour from that appearing in the direction at right angles to it, and the colour in the latter case is usually brighter. Tschermak found, for example, for meroxene—

	Light at right angles to cleavage surface.	Light parallel to cleavage surface.
Colour... ...	Yellow, green, or brown	Yellow, red, and reddish-brown in brighter shades.

The differences in colour are rarely perceptible with the unaided eye, but generally require for their observation the use of a specially constructed instrument called the "dichroscope." The property of pleochroism, therefore, can hardly be said to make more difficult the determination of the colour of mica. Previously such a difficulty arose on account of the fact that the colour depends to a large degree upon thickness. Thin laminæ generally appear colourless, while thick sheets have a shade from medium to dark, and can even be quite black. In deciding the colour, therefore, it is usual to make

use of plates of a definite thickness of between 1 and 2 mm. Such plates of muscovite are generally of bright shades, and yellow, grey, green, and red in colour. A particular Indian species, a muscovite from the mines of Hazaribagh exhibits, when in thick layers, a deep ruby-red colour, and has received, in consequence, the name of ruby mica. Phlogopite exhibits generally very distinct shades. The commercial designation, "amber mica," refers especially to the predominance of amber-coloured plates of this species. Yellow, red, and brown shades are common, although almost colourless varieties also occur. The colour of phlogopite has distinct relation to the chemical composition. The reddish brown varieties contain considerable quantities of fluorine. The green varieties, on the contrary, are poor in fluorine. Occasionally mica plates show a quite remarkable mother-of-pearl effect, the appearance of which is to be traced to the same causes as the similar effect on many kinds of mussel shells. As a result of the laminated structure of the mica, the light is compelled to pass alternately through the substance of the mica, and through the air layers enclosed between the laminæ. This causes a considerable quantity of the incident rays to be totally reflected, and produces the peculiar iridescence. This effect can be produced artificially with suitable plates. By bending the plate the laminæ are loosened, air is admitted, and the conditions for the appearance of the above effect are obtained. Apart from this effect, mica exhibits generally a glassy surface, and sometimes takes on a metallic appearance. The golden or silvery glittering effect exhibited by some pieces is due to the numerous microscopic inclusions, which reflect the light in a peculiar manner. This characteristic is responsible for the names "cat's gold" and "cat's silver," given to such micas in the Middle Ages. The key to the explanation of these names lies perhaps in the expression still common in South Germany of "for the cat," meaning useless, or worthless. Gold for the cat was, therefore, worthless gold, or something looking like gold but in reality no such thing.

Hardness.

The hardness of a mineral is determined by attempting to scratch other minerals with pointed pieces of the mineral in question. This shows which is the harder. In order to develop a universal scale of hardness, Mohs established a series of ten minerals representing different degrees of hardness. They are given the numbers one to ten, the softest being represented by the No. 1, the next harder by No. 2, and so on. The second degree of hardness is represented by gypsum crystals, the third degree by carbonate of lime crystals. The hardness of mica is between these two degrees, as it scratches gypsum and can be scratched by carbonate of lime.

Although the different kinds of mica have practically the same degree of hardness in a mineralogical sense, yet more defined differences in hardness are made in the mica industry, as the hardness of any particular kind often determines its suitability for a particular purpose. The following grades are principally recognised, the first being the softest :—

1. Amber mica.
2. White Indian mica.
3. Soft green Madras and Calcutta mica.
4. Ruby Indian mica.
5. Hard green and brown Madras.
6. Green, brown and yellow East Africa mica.
7. Green United States mica.

In the case of amber mica there is a further commercial distinction between three principal kinds :—

1. Clear, transparent soft amber mica.
2. Streaked amber of medium hardness.
3. Opaque hard amber.

Specific Gravity.

The determination of the specific gravity of the different kinds of mica is beset with special difficulties. Between the fine laminæ of which every

piece of mica is composed, there is always more or less air which it is hardly possible to eliminate. The presence of a considerable quantity of air can be easily shown by immersing the piece in a vessel of water and creating a vacuum over the water, as immediately innumerable air bubbles appear. Attempting to powder the mica is not of much use, as, on account of its structure and slight brittleness, it is not suited to this method. According to Naumann, the specific gravity of phlogopite varies between 2·75 and 2·97; that of muscovite between 2·76 and 3·1. Muscovite is thus the heavier, though the difference is not great. Mica has about the same specific gravity as limestone, marble or aluminium. It is obvious that this high specific gravity renders the cost of transport an important consideration. Indeed, the possibility of mining and realising small quantities often depends entirely upon the cost of transport.

Elasticity.

On the question of the elasticity of mica, one finds in different books exactly opposite views. In one place it is stated that the elasticity of thin laminæ is fairly good, in another that it is quite small. This is due to the different ideas prevalent as to the meaning of elasticity. The later physicists understand elasticity to mean the resistance of the plates to alteration in form or volume; on the other hand, others understand it to mean the capacity of the body to regain its original shape and volume, after the force which has produced a small alteration is removed (Wüllner). This definition corresponds fairly well with the popular understanding of what is meant by elasticity.

Measurements carried out on muscovite plates by Coromilas showed that only very small differences in elasticity exist along different directions within the cleavage plane. The maximum deviation due to the effect of a definite load was obtained parallel to the axis of symmetry, the minimum deviation at an angle of 45° to that axis. The modulus of elasticity

is (according to the tables of Landolt-Börnstein), 22,133 in the direction parallel to the axis of symmetry, and 15,543 in the direction 45° to this axis. A mica bar of one square millimetre section loaded with one kilogramme would, therefore, extend by $\frac{1}{22133}$ of its length in the first case and by $\frac{1}{15543}$ in the second case.

Electrical Properties.

Of particular interest is the conduct of mica under electrical strain. Its dielectric constant * varies with the duration of the charge. Immediately after the application of the charge the conductivity at ordinary temperatures is quite appreciable. According to Liebisch the dielectric constant has for the first fraction of a second a value about 4·6. H. W. Schultze found that the conductivity increased with temperature until it reached a maximum value, sinking again to a remarkably small value at very high temperatures. In the following table giving results by J. Curie, the specific conductivity in C.G.S. units is denoted by c, and the temperature by t.

Duration of charge.	10 seconds.	1 minute.	10 minutes.	60 minutes.
t = 20° C.	c=0·000457	c=0·000103	c=0·000015	c=0·000003
t =100° C.	c=0·001030	c=0·000257	0·000066	—

The dielectric strength or resistance to high electric pressure has been carefully investigated by many, including Steinmetz. In comparison with that of other bad conductors it is remarkably high, for which reason mica is an insulator of the highest value. Steinmetz found the following values for the disrup-

* The dielectric constant of an insulating material is the relation of the capacities of two condensers of the same shape and size, one of which has the material in question and the other air, as the insulating medium.

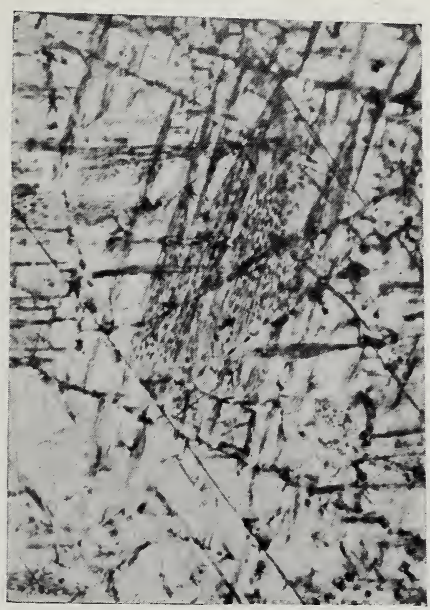

Fig. 10.—Indian Mica from Madras, with streaks and spots of Iron Oxide.

(Photo by Oliver G. Irons, London.)

tive strength at 5,000 volts, the figures being obtained by division of the disruptive pressure by the thickness of the material in millimetres.

Material.	Breakdown voltage per mm.
Air	1,670
Mica	320,000
Dried wood fibre	13,000
Paraffin paper	33,900
Melted paraffin (65° C.)	8,100
Turpentine	6,400
Copal varnish	3,000
Vulcabeston	3,600
Asbestos paper	4,300

It will be seen that mica has by far the highest disruptive strength of all the materials mentioned. Experiments have been made by Walter on the disruptive strength of the different natural kinds of mica. The results for five different varieties are given in the following table :—

Origin.	Colour.	Thickness in cm.	Disruptive strength (volts per mm.).
German East Africa	Light brown in thick layers, free from impurities	0·045 0·070	28.000 28,500
Calcutta ...	Light red in thick layers, a few impurities	0·048	17,500
Madras ...	Thick layers, green, very soft, fairly numerous red and green spots	0·035	24,500
Russia ...	Light yellow, with black impurities	0·048	21,000
Ceylon ...	Thin green layers or thick layers of dark reddish yellow	0 050	20,000

Further measurements of the dielectric strength of mica have been carried out recently by E. Wilson

and T. Mitchell. The disruptive pressure was determined by them between plate electrodes, and also between plate and point electrodes, by means of alternating current of 55 cycles. The capacity was measured by placing the mica between the plates of a condenser, and the values so found were compared with the air condenser. The charging was effected by means of a Ruhmkorff coil, the trembler of which had a frequency of 20 cycles per second. The specific resistance was determined between discs of tin foil 81 mm. in diameter pasted on to the mica and measured according to the usual direct deflection method. The resistance and capacity measurements were taken at a temperature of 9° C., and the results are given in the following tables :—

DIELECTRIC STRENGTH.

Origin and colour.	Thickness in mm. 0·1	0·2	0·3	1·0
	Maximum pressure in millions of volts per cm.			
MADRAS, brown, spotted	1·6	1·2	0·9	—
,, green, ,, A	1·3	1·1	0·9	—
,, ,, ,, B	1·0	0·75	0·5	0·27
,, ,, ,, C	1·3	1·1	0·94	—
,, red, heavily spotted ...	1·9	1·3	1·0	—
,, green, without spots, B ..	1·7	1·2	0·95	—
,, ,, ,, C ...	1·7	1·2	0·9	—
,, ,, ,, D ...	2·0	1·3	0·8	—
BENGAL, spotted	1·1	0·6	0·2	—
,, red, heavily spotted ...	1·6	1·4	1·2	—
,, white	2·5	1·3	0·4	—
,, yellow	2·1	1·4	0·9	—
,, red, transparent	2·1	1·4	0·9	0·72
CANADA, amber	1·5	1·1	0·8	0·5
SOUTH AMERICA, spotted	1·0	0·6	0·4	—
,, red, transparent...	2·1	1·4	0·9	—

Specific Capacity and Specific Resistance.

Origin and colour.	Thickness in mm.	Capacity reduced to Air = 1.	Specific resistance in 10^{12} ohms per cubic cm.
Madras, brown spotted	2 77	2 5	22·0
,, green spotted, A ...	2·1	4 8	16 0
,, ,, ,, B ...	1·7	5·1	15 0
,, ,, ,, C ...	1·43	3 9	91·0
,, red, heavily spotted ...	2 4	4·4	55 0
,, transparent, green B...	1 73	4·4	133 0
,, ,, ,, C...	1·61	4·5	81 0
,, ,, ,, D...	1·8	3·9	125·0
Bengal, spotted	2·04	4·3	45·0
,, red, heavily spotted ...	2·5	4·7	20·0
,, white	1·4	4·2	7·0
,, yellow	1·4	2·8	80·0
,, red, transparent ...	1·9	4·2	118·0
Canada, amber A	2·1	2·9	3·4
,, ,, B	5 0	3·0	0·44
,, ,, C	1·4	2·9	22·0
South America, spotted	1·22	5 9	39·0

The surface conductivity of mica is not inappreciable. Quantitative figures cannot be given, as exact measurements are not available. As mica is a poor conductor of electricity it becomes electrified by friction. The character of the charge depends on the kind of rubbing material, and also on many circumstances, such as the nature of the surface. According to these it is sometimes negative and sometimes positive. An electrical charge is also produced when mica plates are rubbed against one another. When laminæ of sheets are separated, one cleavage surface is positive, the other negative. If a thin sheet of mica is torn sharply through in a completely dark room, a greenish light appears at the torn edge, the light being stronger when a sheet made up of several laminæ is torn. This phenomenon may probably be traced to the appearance on the torn edges of opposite charges which are sufficiently large in the case of a sudden tear, to produce a discharge in the form of a spark.

Thermal Properties.

Besides the disruptive strength, resistance to heat is an important characteristic of any insulator, and, in this respect also, mica possesses high qualities. If transparent and fairly thin sheets of muscovite or phlogopite are heated to a temperature of 400° C. to 600° C. no perceptible alteration is evident; their transparency and elasticity is retained. At higher

Fig. 11.—Mica Crystal from Canada shewing the Hexagonal Shape and Growth Zones.

(*Photo by Oliver G. Irons, London.*)

temperatures, between 900° C. and 1,000° C., muscovite becomes silver white with a pronounced metallic appearance, loses considerably in transparency, and becomes rather brittle, so that it can be pulverised into a thin white dust. Phlogopite withstands this temperature much better; it loses only a little in transparency, and does not become so brittle. At very high temperatures both micas melt,

the dark kind appearing to melt easier than the light kind. Under the oxy-hydrogen blow-pipe they melt easily and boil down to a grey or yellowish glass. Experiments in a furnace with means for measuring temperature gave melting points between 1,200° C. and 1,300° C., according to the kind of mica. Only very fine particles of mica can be melted in the ordinary blow-pipe. Von Kobell has set up a scale of melting for minerals comprising six degrees: No. 1 has the lowest and No. 6 the highest melting point. Muscovite and phlogopite are placed by him between the fifth and sixth degrees, melting easier than bronzite, but not so easily as adular.

If a glowing hot piece of mica is taken out of the fire and cooled suddenly in a cold air blast, it suffers no damage even if this treatment is repeated. Even if water is allowed to drop on a hot sheet of mica, the sheet is not cracked or burst, except for a small amount of scaling. Mica is also practically insensitive to sudden changes of temperature.

Bad conductors of electricity are nearly always bad conductors of heat, and mica follows this rule. If a strip of muscovite 1·3 cm. wide and 0·25 mm. thick is heated for a minute at one end to a bright red, one can still comfortably hold it with the bare fingers at a distance of 3 cm. from the heated end. The same is the case with phlogopite. It is not improbable that the heat conductivity parallel to the plane of symmetry is of a different value to that at right angles to it, but such measurements have not yet been made. The conductivity will probably be least in a direction at right angles to the cleavage plane, on account of the laminated structure. With regard to the transparency of mica for heat rays, we have been unable to find statements based on measurements. As such information has, however, considerable practical value, we have ourselves made experiments with a differential thermoscope, which, although not suitable for exact physical measurements, gave results which are suitable for a general discussion. The transparency of mica was compared with that of window-glass of 1·66 mm. in thickness.

Taking the transparency of the latter at 100, the value obtained for most of the mica plates investigated was about 60 ; in other words, the transparency of mica to heat rays compared with that of the glass plate in the proportion of 6 to 10. As the transparency of window-glass to heat is already very small, one can place mica amongst the adiathermic bodies.

By the expression specific heat, is understood the quantity of heat which must be added to one kilogramme of a body in order to raise its temperature by one degree centigrade. Of all materials, water has the highest specific heat; that is, in order to warm one kilogramme of water by one degree, more heat must be added to it than to a kilogramme of any other material. If the specific heat of water is denoted by one, mica, according to Ulrich, has the following values :—

Alkali mica, 0·2080.
Magnesium mica, 0·2061.
Sodium mica, 0·2085.

It is therefore about the same for different micas, and of a value about one-fifth that of water. If one imagines one kilogramme of mica and one kilogramme of water being heated by burners of the same strength, a temperature of say 100° will be reached by the mica five times as quickly as by the water. For comparison it may be mentioned that the specific heat of aluminium is 0·22, and that of plate glass 0·186.

CHEMICAL PROPERTIES.

Micas are, from a chemical point of view, silicates of alumina and alkalies, in many cases also combined with magnesia and iron oxide. Among those kinds with which we are concerned, biotite is distinguished by its high content of magnesia (from 10 per cent. to 30 per cent.), and by its often considerable content of iron from muscovite, which is, on the other hand, richer in alumina and silicic acid. Both micas practically always contain some water, which is only eliminated by continuous heating at a high temperature. The maximum water content is about 7 per cent. for muscovite, about 15 per cent. for biotite, and considerably less for most other varieties. Fluorspar is present in both micas, more so in muscovite (about 4·15 per cent.) than in biotite. When present with water it disappears on the mica being brought to a glowing heat. Iron can be quite absent in both micas. The maximum found in muscovite has been 8·8 per cent., but considerably more has been found in biotite. Besides the normal constituents, many subsidiary impurities occur, and these are collected together under one heading in our tables. Sodium occurs occasionally together with potassium, at times also lithium, together with silicic acid, titannic acid, also chronium oxide, together with alumina and iron oxide. Biotite occasionally contains also rubidium, manganese, barium, calcium, and also traces of cobalt and nickel. As shown on the table on p. 39, biotite often contains

the lower oxide of iron in considerable quantities, as well as the higher oxide. The determination of the

Fig. 12.—Intergrowth of Biotite and Muscovite, Norway.
(*Photo by Oliver G. Irons, London.*)

composition of mica is beset with no small difficulties. The different kinds are often completely intergrown one with another, or the crystals contain inclusions

of different kinds, so that it is very difficult to obtain a pure and homogeneous mass for the investigation. Tschermak, to whom we are indebted for a series of excellent analyses, divided the plates into fine laminæ, in order to obtain pure samples. These were selected under the magnifying glass, and then finally under a microscope. It should further be noticed that many micas undergo a gradual transformation into other minerals. If such a piece is analysed, incorrect results will be obtained, as the original mica is now mixed with the mineral into which it has changed. For research purposes, therefore, freshly mined crystals must be employed. Not only the material, therefore, but also the analysis, has its pitfalls. On account of the presence of fluorspar certain treatments are rendered more difficult. Again, the lower oxide of iron must be determined separately from the higher oxide, because, if not, the results will give an incorrect determination of the composition. Even the determination of the water content offers particular difficulties. This is not the place in which to describe how these difficulties have been overcome, but in the following tables are given the results of a series of analyses.

The comparison of the first two vertical columns of Tables I. and II. shows that muscovite contains more silicic acid and aluminium than the micas belonging to the biotite group; on the other hand, the greater content of magnesia and iron in the latter is readily seen. Again, it sometimes happens that many biotites contain more potassium than the potassium micas. In spite of the high content of potassium, muscovite is generally more homogeneous and larger. Amongst the subsidiary constituents is found calcium oxide, which is occasionally found in muscovite and biotite, but is quite an unimportant constituent.

At this point a word should be said as to the relation between phlogopite and biotite. We have already in the Introduction followed Hintze in classifying phlogopite as a slight variety and not as a different species from biotite. Tschermak and Naumann, on the contrary, prefer to classify phlogo-

pite separately. There is no reason for this, as the formula for phlogopite agrees completely with that of biotite (meroxene), and is distinguished chemically from the latter only by its smaller iron content. The analysis of Table II. referred not only to such magnesium micas poor in iron, but also to all biotites. To be exact, the composition of phlogopite should be expressed in the following manner :—

SiO_2	41% to 44%
Al_2O_3	13% to 15%
FeO	1% to 2%
MgO	27% to 29%
K_2O	8% to 10%
Na_2O	1% to 2%
F	1% to 4%
H_2O	0·5% to 3%
Li	Traces

As the analyses show considerable variation in the proportions of the constituents of mica, it is particularly difficult to discover the laws according to which its chemical composition is determined. We cannot here, unfortunately, go into the theories of Rammelsberg, Tschermak, and Clark, but must refer those who wish to go into the matter further to their original works.* The question of the chemical composition of mica, however, is even to-day by no means satisfactorily solved. Many biotites may be represented by an ortho-silicate $\overset{I}{R}_1 \overset{II}{R}_2 \overset{III}{R}_3 (SiO_4)_3$ in which $\overset{I}{R}$, $\overset{II}{R}$, $\overset{III}{R}$ represent univalent, bivalent, and divalent metals.

$$\overset{I}{R} = H, K$$
$$\overset{II}{R} = Mg, \overset{II}{Fe}$$
$$\overset{III}{R} = Al, \overset{III}{Fe}$$

Tschermak considers them to be isomorphic mixtures of the combinations $HK_2Al_3Si_3O_{12}$ and Mg_2SiO_4, generally in the proportion of 1 to 3.

* Tschermak, *Proceedings of the Academy of Vienna*, vol. 76, July issue, and vol. 78, June issue. Further *Zeitschrift fur Krystallographie*, II. 1878, 14, and III, 1879, 122. Rammelsberg, *Ann. d. Phys. u. Chemie*, N. F., Vol. IX, 1880, 113 and 302. Clark, *American Journal of Science*, Vol. 38, 1889, 284.

CHEMICAL COMPOSITION OF MICAS.

I. MUSCOVITE.

Origin.	SiO_2.	Al_2O_3.	Fe_2O_3	MgO.	K_2O.	H_2O.	Including also	Authority.
Zillertal, Tyrol	45·87	30·86	5·70	1·[illegible]6	9·07	4·60	1·69FeO, 0·23CaO, 0·54Na_2O	Sipöcz.
Utö, Sweden	47·50	37·20	3·20	0 90*	9·60	2 63	0·53F	H. Rose.
Ytterby, Sweden ...	45·21	33·40	2·78	1·58	10·71	4·28	0·94F, 2·00FeO, 0·42Na_2O	Rammelsberg.
Ochotsk, Russia ...	47·19	33·80	4·47	2·61†	8·55	3·64	0·52F	H. Rose.
Bengal	45 57	36·72	0·95	0·38	8·81	5·05	1·28FeO, 0·21CaO, 0·19Li_2O, 0·62Na_2O, 0·15F	Blau.
East Indies	45·71	36·57	1·19	0·71	9·22	4·83	1·07FeO, 0·46CaO, 0·79Na_2O, 0·12F	Sipöcz.
Otakisan, Awa, Japan ...	53·01	34·70	Spur	0·50	6·05	4·67	0·27CaO, 1·01Na_2O	Takayama.
Culsagee Mine, North Carolina	45·62	35·93	2·93	0·34	9·40	4·93	0·71Na_2O	König.
Rio de Janeiro	47·60	35·70	4·31	0·59	6·[illegible]7	4·04‡	0·43CaO	Hauer.
Auburn, Maine	44·48	35 70	1·09	a trace	9·77	5·50	1·07FeO, 2·41Na_2O, 0·10CaO, 0·72F	Riggs (Clarke).
Massachusetts	47·02	36·83	0·51	0·26	9·80	3·90	F0·52 Na_2O, 0·30MnO1·05	Rammelsberg.

* incl. Mn_2O_3. † incl. MnO. ‡ incl. F.

II. BIOTITE.

Origin.	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	K_2O.	H_2O.	Including also.	Authority.
Kaiserstuhl	36·42	17·92	2·83	7·04	20·52	6·54	2·50	3·99TiO_2 2·60Na_2O	Knopp
Bodenmais	40·86	15·13	13·00	—	22·00	8·83	0·44	—	Kobell
Aschaffenburg	36·48	17·93	3·97	4·10	19·50	8 75	1·69	3·84TiO_2 2 98Na_2O 0·41CaO	Niemeyer
Vesuvius	44·63	19·04	4·92	—	20·89	6·97	0·17	2·05Na_2O	Kjerulf
Vesuvius	39·30	16·97	0·48	7·86	21·89	7·79	4·02	0·59MnO 0·49Na_2O 8·82CaO 0·89F	Berwerth
Langesundfjord, Norway.	39·05	6·84	24·89	7·47	4·05	9·03	2·27	2·41MnO, 2·13Na_2O 0·78CaO, quantities of TiO_2	Flink
Miask, Russia	40·00	12·67	19·03		15·70	5·61	—	1·63TiO_2 0·63 Mn_2O 2·10F	H. Rose
Ceylon	42·26	15·64	0 23	1·52	27·23	8·68	2·91	2·19F	Popovits
Bengal	38·10	18·35	—	6·53	23·57	8·91	0·40	0·35TiO_2 0·62BaO 3·44Na_2O	Frenzel
Culsagee Mine, U.S.A. ..	33·93	17·38	5·42	0·50	23·43	—	19 17	0·35NiO	König
,, ,, ...	33·77	17·56	5·61	0·50	22·48	—	20·30	? NiO	Chatard
,, ,, ...	34·00	20·36	4·91	0·42	21·71	—	18·50	0 57NiO	,,
East Nottingham, U.S.A.	35·89	7·45	8·78	1·13	31·45	0·46	14·33	—	Munroe (Cook)
,, ,, ..	35·26	7·58	9·68	0·32	31·51	0·61	14·78	—	,, ,,

The muscovites are considered by Rammelsberg to be also ortho-silicates, and to be expressed by the formula $\overset{\mathrm{I}}{R}AlSiO_4(\overset{\mathrm{I}}{R}=H, K)$. If H and K are in the proportion of 2 to 1, as appears to be usual, then we have $H_2KAl_3Si_3O_{12}$, and the theoretical composition becomes—

SiO_2	45·2
Al_2O_3	38·5
K_2O	11·8
H_2O	4·5

This is very near the values for East Indian mica given in Table I. The presence of Fe_2O_3 and other substances cannot simply be set aside as a case of impurity. Tschermak explains this on the assumption that small and varying quantities of mica containing, for example, iron, have been mixed with the pure muscovite.

Muscovites offer considerably more resistance to outside chemical action than the biotites, while amongst the latter the phlogopites with small iron content are less easily acted upon than those rich in iron. Muscovite is only very slightly sensitive to atmospheric effects. It weathers well, lasting longer the smaller the content of iron, sodium, magnesia and lime. Chemical action generally prepares the way for mechanical destruction. If water, for example, penetrates between the laminæ of a crystal, the cleavage surfaces are opened out, especially if frost has set in. The crystals finally split up into numerous small scales, and the exposed surface is enormously increased. If iron oxide is present it is converted to hydroxide and the mineral assumes gradually a colour, and sometimes at this stage has a metallic or golden appearance. The colours then dull, the scales become torn and decayed, and finally fall to pieces entirely. If water containing carbon-dioxide is present, the mica eventually decomposes into alkaline substances. The final result is a yellow-coloured mass due to the presence of iron hydroxide mixed with the numerous little scales of mica which have not yet been decomposed. If manganese oxide is present this also is changed into hydroxide.

In the case of biotite also, decomposition is accompanied by a change of colour which may run through a complete scale of colour variation. The elasticity diminishes as the mica becomes weathered, and the scales break up and change finally into a muddy clay containing iron and traces of calcium carbonate and magnesia. It is not always the case that biotite changes to clay; it often first loses its titannic acid in the form of rutile, and then changes into chlorite or epidote. Changes to serpentine, spinel, and augite are also known. The behaviour of the two micas under the influence of laboratory treatment is also different. On continual heating with concentrated sulphuric acid, magnesia mica is completely decomposed, leaving behind a white deposit of silica. Potassium micas, on the other hand, are not attacked by either hydrochloric or sulphuric acid. Warm hydrofluoric acid and molten potassium hydrate attack the surfaces of mica crystals. If the action is stopped at the correct moment etch-figures are obtained (see page 14). If mica is heated in the presence of alkaline carbonates it is decomposed, and this treatment is adopted in making chemical analyses. Mica resists to a very high degree the action of gases, as, for example, gases produced as a product of combustion.

Great care must be taken to avoid the contact of mica with oil, as may happen, for example, in electrical machinery. As far as we can judge, this action of oil is not chemical, but mechanical. It penetrates into the narrow interstices of the laminæ of which the mica plate consists, and reduces the cohesion of the leaves so that the mica falls to pieces.

It is more of theoretical than practical interest that it has already been possible to produce mica artificially. Von Chrustschoff obtained an artificial silicate glass by melting together in a platinum crucible the average constituents of ferro-magnesium mica, together with an equal quantity of a mixture of potassium silico-fluoride, sodium fluoride, aluminium fluoride, magnesium fluoride, and some amorphous silicic acid. The resultant material had the following composition :—

SiO_2 42·41%	FeO 8·11%	MnO 0·15%
TiO_2 1·07%	CaO 16·52%	MgO 9·71%
Al_2O_3 17·27%	Na_2O 2·65%	K_2O 2·13%.

He allowed this mass to cool slowly after having raised its temperature several times quickly to the melting point. The product was a grey porous blistery substance which was easily pulverised. It was full of innumerable thin dark brown scales of mica of a maximum size of from 2 to 3 square millimetres, and mostly of sharply defined hexagonal shape. Analysis gave the following composition :—

SiO_2 39·11%	FeO 8·55%	CaO 0·83%	F 1·65%
Al_2O_3 18·09%	MnO Traces	K_2O 7·23%	
Fe_2O_3 2·17%	MgO 20·19%	Na_2O 1·74%.	

The specific gravity was determined to be 3·021.

Dölter succeeded also in reproducing mica by melting in a platinum crucible natural silicates with sodium fluoride and magnesium fluoride. He also obtained an almost pure potassium mica by melting together in the same way andalusite with potassium silico fluoride and aluminium fluoride. The pieces he obtained were about 1 millimetre in diameter, hexagonal in shape, had a silver-white colour, and glittered like mother-of-pearl. The specific gravity was 2·950. The axial angle was found to be considerably smaller than that of natural muscovite, and the material was also found to be unaffected by hydrochloric acid.

GEOLOGICAL OCCURRENCE.

With the exception of quartz and Iceland-spar, there is hardly any other crystalline mineral which is so widely distributed in the various layers of the earth's crust as mica. In the composition of many rocks spread over the whole world, mica plays a most important part, and also accounts for the stratified structure of the rock in cases where the scales of mica lie parallel.

In crystalline rocks potassium mica occurs particularly in conjunction with a feldspar rich in silicic acid, especially with orthoclase, while biotite occurs often with oligoclase and hornblende, taking the place of the latter in many cases, as, for example, in some syenites, in diorite, porphyrite and andesite. Biotite, as well as muscovite, is present in the most important mica rocks, such as granite, gneiss, and mica schists. Biotite is also a more or less important constituent of many other stones, as, for example, of granulite, the stratified structure of which is increased by its presence, in amphibolite, gabbro, norite, melaphyre, in many basalts, porphyrys, in trachyte, phonolite, and elæolite syenite.

If these rocks are distintegrated and built up again, new kinds of rock are produced, known as clastic sedimentary rocks. Only potassium mica appears in these, as the easily decomposed biotite disappears during the change. We thus come across muscovite in sand, sandstone, graywacke, and breccia. Finally, mica (biotite) is present in volcanic products, for example, in many tuffs, and in volcanic sands. It is one of the chief constituents of the discharged matter

from Vesuvius, and is sometimes expelled in the form of particularly good crystals, which are most suitable for mineralogical research, on account of their perfect character. The above mentioned may be termed "primary micas," while those micas produced by the transformation of other minerals may be termed "secondary micas." As this change extends in nature over a long period, one often finds specimens in which the various stages of the transformation can be followed. The original mineral, when of crystalline character, occasionally also retains its outer form, and the new mineral produced appears in a pseudomorphous form. Thus, for example, corundum can change into muscovite. The monoclinic mica then compares with the rhombohedral form of corundum, although it does not correctly belong to it.

Secondary muscovites can result from the following minerals : disthene, tourmaline, fibrolite ; from corundum, either direct or with disthene and fibrolite as intermediate steps ; from andalusite, cordiolite, nepheline, topaz, zoisite, elæolite, garnet, scapolite, and potash feldspar. Secondary biotites are produced from hornblende, tourmaline, augite, fassaïte, and from corundum with chlorite as intermediate.

While mica is found almost universally, the occurrence of deposits which yield sheets of commercial value is rare. As a source of mica, India takes the first place and yields more than all the other countries of the world together. Canada and the United States come second, with approximately equal production. German East Africa comes a poor third, but, nevertheless, exports more than all the remaining countries together. The latter include Brazil, Argentine, Norway, Siberia, South Africa, Japan, and China. The mica obtained from most of the above sources is potassium mica. Phlogopite deposits of commercial importance are found only in Canada and Ceylon.

Muscovite of a good enough quality to be mined is found nearly aways in veins of pegmatite. Pegmatite can be described as a kind of granite. It

has the same principal constituents as granite, viz., feldspar, chlorite, and mica, but in an uncommonly

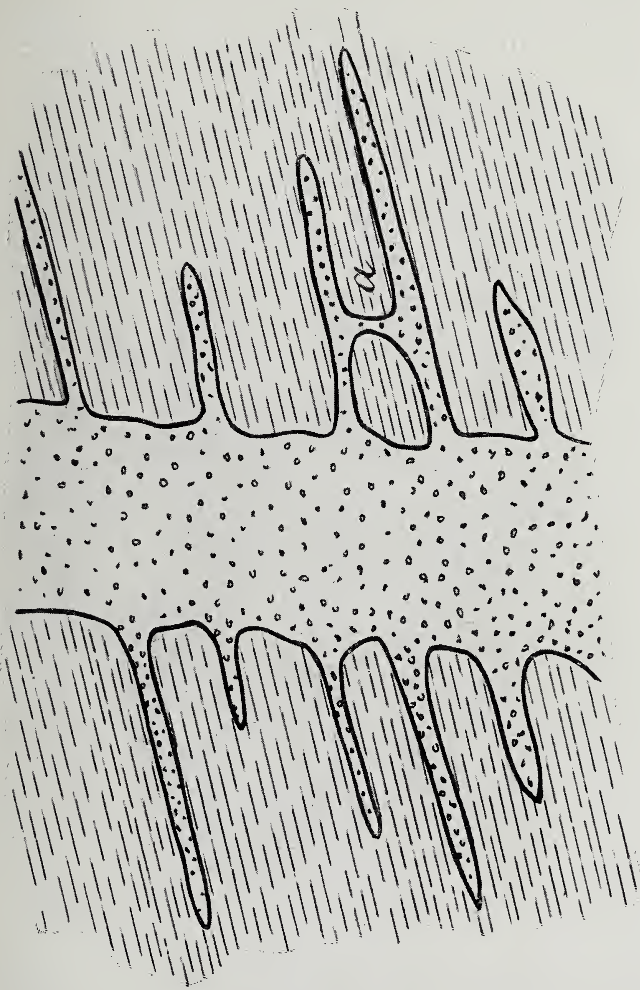

Fig. 13.—Pegmatite Vein in Mica Schists.
(*a*) *Apophysis.*

coarse form. Thus, the feldspar crystals may be as large as a foot in diameter, and the mica is often found in enormous plates embedded in the rocks.

Occasionally other minerals occur in the mixture, such as tourmaline, beryl, topaz, garnet, and andalusite.

Pegmatite is generally in the form of veins, with branches in the neighbouring rock, and sometimes encloses portions of this rock, showing the penetrating character of the pegmatite. As a rule these veins lie in the direction of the strata of the rock, obviously because they can pierce through the rock easier in this direction than in any other. Fig. 15 shows a vein which has penetrated through a stratified rock. The branches which extend sideways all run parallel to the stratification, that is, in the direction of least resistance. An Apophysis is shown at the point *a*. If a fault strikes across a vein of pegmatite, as shown on the illustration on page 47, a thickening of the vein occurs at this point, and this is often accompanied by a larger proportion of mica crystals.

Very different opinions have been expressed as to the origin of pegmatite veins. We will here mention only the theory of Charpentier, which has of recent years gained increasing support. According to this theory, pegmatite is fundamentally of plutonic origin. The original fiery fluid mass is supposed to have cooled gradually from above, and hardened into granite, which can subsequently be transformed into gneiss. A portion of the mass remains in a fluid condition under the recently cooled rock. As the water-free minerals crystallize out of this fluid magma first, it contains considerably more water than that which has already hardened, and can therefore remain fluid at a much lower temperature. Compressed from above, it penetrates into the fissures and cracks of the rock, and eventually hardens, although much slower than the other rock on account of the high water content. As a result of this slow hardening, the molecules have time to form themselves into large crystals. In this way the coarse-grained structure of pegmatite is clearly accounted for.

The length of pegmatite veins varies considerably. The thickness varies from a few inches to several hundred feet. As a rule veins of less than, say, three

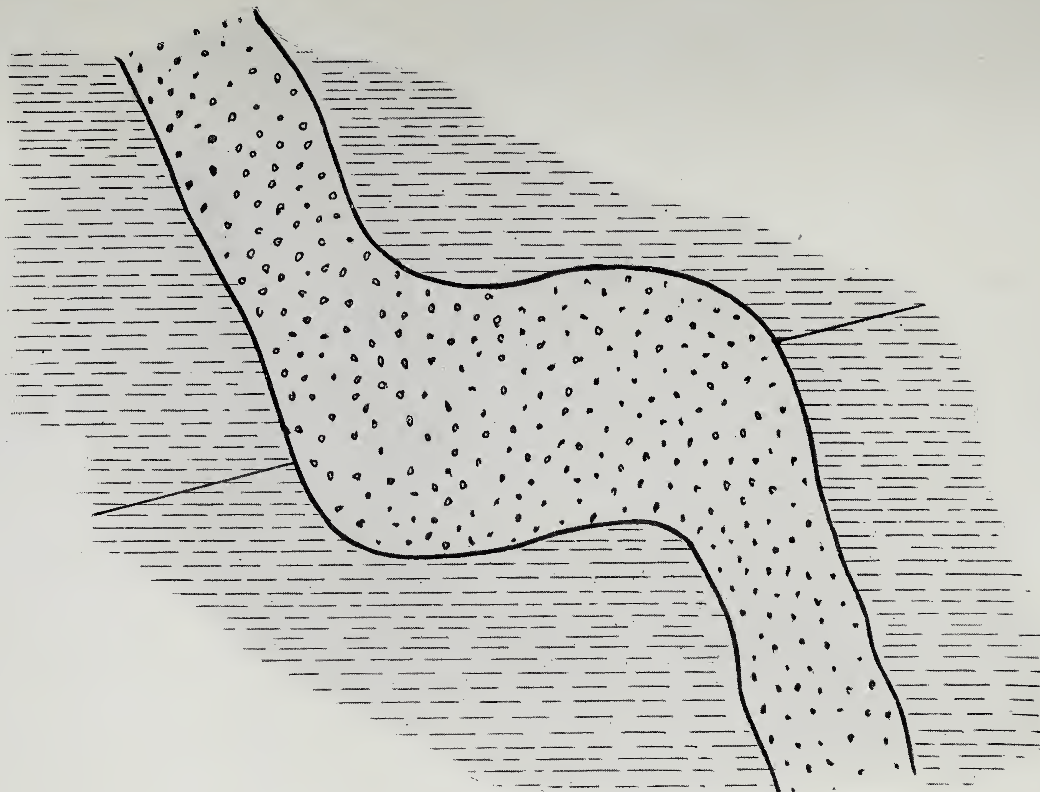

Fig. 14 --Pegmatite Vein struck by a Fault.

or four feet in thickness do not contain mica crystals of any value, and even large veins do not always contain pieces of great commercial value. There is no definite means of determining the richness of a vein, so that the establishment of a mine is always somewhat speculative. The mica crystals are found irregularly distributed in the interior of the veins, but occur in greater quantities in the outer portions near the surface of contact with the surrounding rock.

Phlogopite occurs in somewhat different circumstances. In the same way as muscovite is always associated with pegmatite veins, phlogopite is invariably found in veins of pyroxenite, so that the former may be termed "pegmatite mica" and the latter "pyroxenite mica."

Pyroxenite veins are found partly in gneiss and partly in crystalline limestone. The veins are in the form of a granular rock, consisting mainly of feldspar and pyroxine. The colour varies from a bright grey or greyish green to dark green. Contrary to pegmatite, these veins occur in regular form without the numerous sideway branches. Besides mica they contain often apatite, calcite, and hornblende.

Very little is known definitely concerning the origin of pyroxenite veins. Cirkel is of the opinion that they are of plutonic origin, in which case the pyroxine will have risen up as a fiery fluid mass and penetrated into the rock above, chiefly along faults, and into crevices where the least resistance is offered. Phosphoric acid gases will have penetrated at the same point, and will have changed the chalk partly into apatite (phosphate of lime). The production of mica can then perhaps be imagined, in that the chalk of the pyroxine combines with the phosphoric acid to form apatite, and that the remaining substances, magnesium, iron, and silicon, combine with potassium and water to form mica. At any rate, we must presuppose the existence of gneiss, *i.e.* crystalline limestone. The pyroxenite penetrates into this and is followed by the production of phlogopite, apatite, and calcite. The phlogopite crystals are occasionally

found embedded in calcite, showing that they must have been formed previous to the latter.

Two distinct kinds of phlogopite deposits can be distinguished, viz., contact deposits, and pocket de-

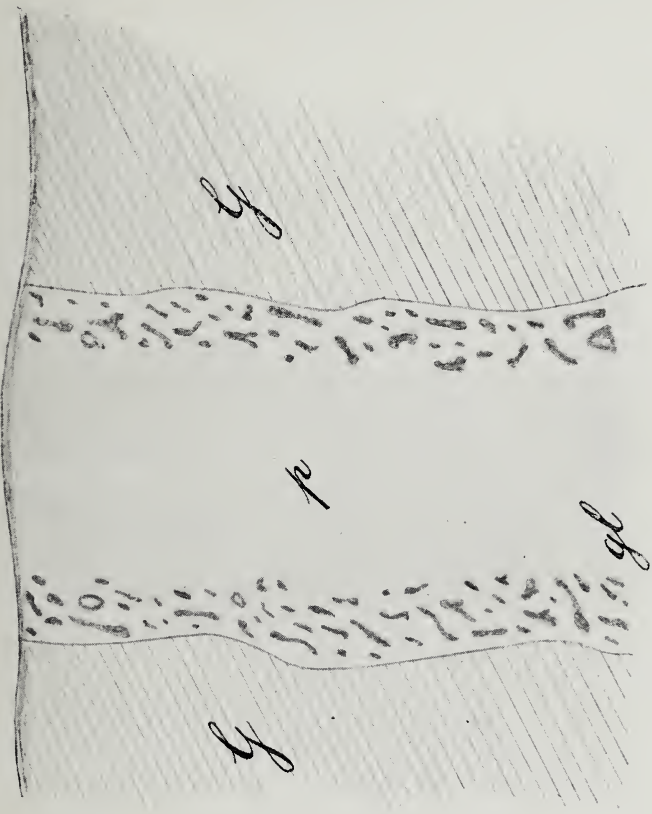

Fig. 15.—Pyroxenite Vein (*p*) in Gneiss (*G*) showiug Mica (*gl*) in the Contact Zone.

posits. In the contact deposits the mica crystals lie at or near the contact surfaces, and usually the plates are found confined together in more or less compact masses, as shown in Fig. 16. This is of great importance in the mining operations in that a relatively small amount of foreign rock has to be extracted. Mica is usually accompanied by calcite, which gener-

ally occurs near the gneiss. Its presence is welcomed by the miners as it often enfolds mica crystals of great beauty and perfection.

Pocket deposits are not so favourable for mining. In these the mica crystals are irregularly distributed, and the groups of pieces occur only at wide intervals in the pyroxenite vein. As a result a large amount of worthless rock has to be extracted in order to reach the mica, and the cost of mining the latter is increased accordingly. Another disadvantage of pocket deposits is the uncertainty as to whether further working will expose more mica. There is no certain means of determining this, and so such deposits are of considerably less value than contact deposits. In many cases they yield only a small percentage of useful mica; generally a large portion of the crystals obtained are distorted, and therefore without commercial value. Nevertheless, there are many excellent mines of this nature.

Canadian Mica.

Let us again consider the geographical distribution of the most important mica districts. Canada contains both muscovite and phlogopite deposits, of which the latter produce the largest proportion of the output of this country. All the mines lie in the zone of the so-called "laurentian" formation, the gneiss of which is the oldest rock exposed on the surface of the earth. These rocks are known as the primitive gneiss formation. The laurentian formation in North America comprises two zones. The north zone runs from the Arctic in a south-east direction to the Mississippi, and stretches from there through Minnesota and Wisconsin to Lakes Superior, Huron and Ontario, and runs north of the St. Lawrence river to the Atlantic Ocean. The second zone, the appalachian, commences on the south bank of the above river, near the mouth, and runs in a south-westerly direction parallel to the coast, to Alabama. Both zones are rich in mica deposits. The Canadian mines lie in the first zone, while the mines of the United States belong for the greater part to the appalachian

zone. The pyroxenite deposits are mainly in the Frontenac county and between the north-east corner of Lake Ontario and Ottawa. They are thus in the

Fig. 16.—Pyroxenite in Gneiss (*G*) showing Mica Deposits (*gl*) in Groups.

provinces of Quebec and Ontario and cover the Liévre district, the Gatineau river and the western district, including the counties of Frontenac, Lanark, and Leeds.

While the phlogopite deposits are confined to a

comparatively small area, the Canadian muscovite deposits are, on the contrary, widely distributed, a circumstance from which the mica industry profits very little. These deposits are predominantly pegmatite in character, and extend throughout the provinces of Quebec, Ontario, and British Columbia.

United States Mica.

The greater proportion of mica obtained in the United States is potassium mica. We have already mentioned the appallachian zone. In this zone lie the mines of New Hampshire and North Carolina, which yield the larger proportion of the whole output of the country. Mica is also found in other States of the appallachian zone, viz., in Maine, Georgia, Alabama, and Virginia, but only in the last named is a continuous industry kept up. Another district lies in the Rocky Mountains. In numerous States where mica is found the deposits are only partially worked, on account of the heavy freight due to the great distances from the railways. Thus, in Utah, Wyoming, New Mexico, Nevada, Colorado, and California no regular and continuous mining is carried out. On the contrary, South Dakota has a fair production, and the yield of Idaho may perhaps be of importance in the future. Since 1895 mica has been mined on systematic and modern methods, and the yield has increased yearly.

Indian Mica.

The greatest proportion of the world's production of mica comes from India. Here there are three main mining districts, separated by fairly large distances. These are in the provinces of Bengal, Madras and Rajputana. The most important mines of Bengal lie in the neighbourhood of the towns of Gaya, Hazaribagh and Monghyr. The mica occurs here in pegmatite veins, in schist or in gneissic granite. The schist belt forms an irregular escarpment with a number of steps which lead from the gneiss plateau of Hazan to the valley of the Ganges.

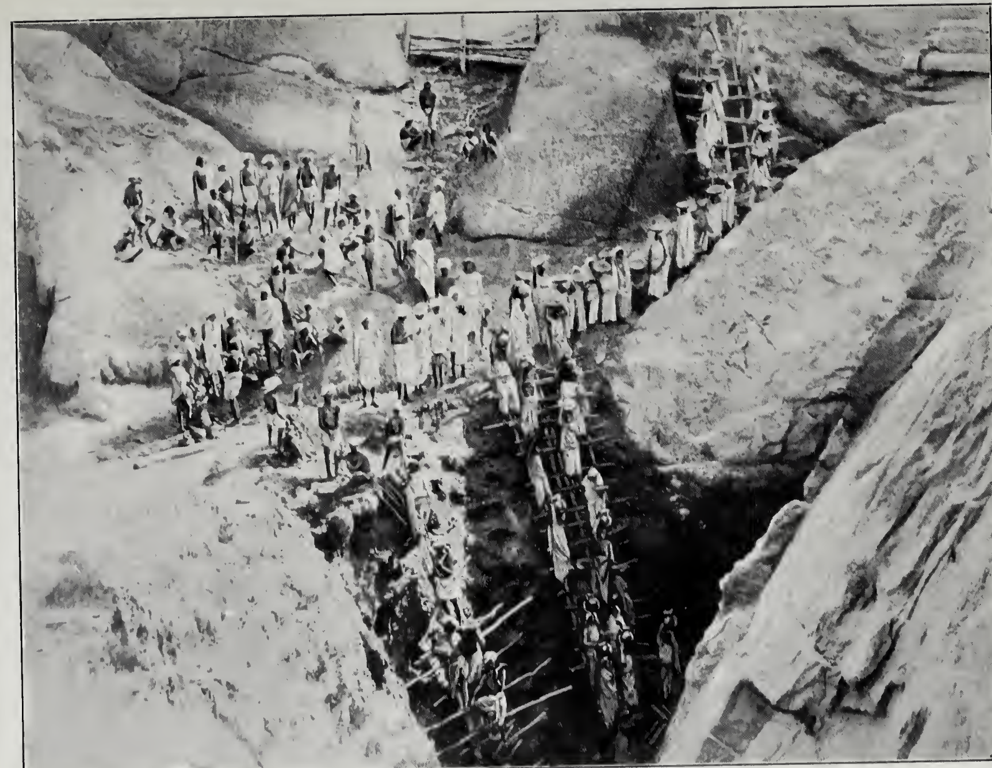

Fig. 17.—The Mouth of an Indian Mica Mine.

Fast-flowing rivers have so opened up the surface that the veins of pegmatite are easily accessible, and mining operations are thus considerably facilitated and cheapened. The mining district comprises a strip of land 12 miles broad and 60 miles long. In 1902 there were 250 mines working in this district, but the number will have increased since then. This district is so rich in mica that the quantity which has already been extracted is insignificant in comparison with that which still exists.

The physical characteristics of the Madras district are not so favourable to mining. There is no natural exposure of the veins as in Bengal, as here the principal deposits lie in a plain. The most important places are Nellore and Nilgiti. The districts between latitudes 14 and 15, some 30 or 40 miles west of Nellore, have been fully investigated geologically. Well-defined layers of gneiss, mostly covered by more recent layers of rock, are spread out in the form of a V, the point of which points south. Between the legs of the V there are schists penetrated by pegmatite veins, and this pegmatite is often very rich in muscovite of high commercial value. The production for 1908 was just short of one-third of the total output of Bengal (11,250 cwt.).

The mining district of Rajputana is still very young. It has yielded considerable quantities since 1905. In 1908 it produced rather more than one-half as much as Madras (6,235 cwt.). In this district also the mica is first extracted from pegmatite veins which have penetrated into the gneiss.

Four commercial kinds of mica are distinguished in India : (1) ruby mica, (2) white cloudy mica, (3) spotted mica, and (4) brown or green mica.

African Mica.

The German East African deposits were opened up about the same time as those of Rajputana. Numerous deposits have been discovered there which are capable of yielding a good mica. The workable deposits are principally those in the Uluguru mountains

and the neighbouring districts. The biotite gneiss here is penetrated by a pegmatite vein of from 10 to 20 metres in width, which contains muscovite. Plates of good quality are frequently found, but they are often distorted or impure. The value of the deposits is as yet uncertain. There is also a lack of good and cheap means of transport, and consequently the production of German East Africa does not hold the position that it might. The most extensively mined districts at present lie on the Mbakana, a tributary of the Mgeta, and in the district north of Morogoro. In the former are the mines of the Morogoro Mica Works (formerly A. Prusse), and in the latter the mines of the German East African Mica Works (formerly W. Schwarz). In numerous other places mica is found and worked to some extent. Pegmatite mica deposits have also been discovered in the German Cameroons, in the district of Esudan (Ossidingue), and are probably suitable for mining.

The German production of mica for the year 1910 was 160,580 kilogrammes, of a value of 320,720 marks.

PRODUCTION AND WORKING.

Mica extraction is a special branch of the mining industry. It is not purely a matter of extracting masses of material as in the case of ore mining where the production of a great mass of material is the great aim, and where it is quite immaterial whether the ore is obtained in large or small pieces. Mica extraction cannot either be directly compared with quarrying, as building stones, slate, and gypsum occur generally in compact masses, wholly suitable for extraction, whereas mica plates are more or less distributed in the rock. It is always necessary to extract the intermediate rock in order to reach further deposits of mica, a circumstance which naturally much increases the cost of mica extraction. In North Carolina, for example, it is necessary on an average to extract one ton of rock in order to produce 200 grammes of commercial mica. Further, while the value of ore, salt, or coal deposits can be predetermined with a great degree of accuracy, it is never certain in mining for mica whether the yield will pay for the construction of the pits and galleries. This circumstance is largely responsible for the fact that mica extraction is so largely carried on in a primitive manner.

The mines are partly underground and partly surface-worked, according to the position and extent of the pegmatite or pyroxenite veins. The extraction is simplest and cheapest when the rock enclosing the mica is already broken up by exposure, and can therefore be easily separated. On reaching hard rock it is necessary to call in the aid of explosives, and then particular care is needed in order that the mica present shall not suffer. Unfortunately, there is a lack of good labour in many districts. Mica extraction requires skilled labour more than mere strength,

and consequently negro or coolie labour is not suitable.

In both America and India many veins contain

Fig. 18.—Mica Crystal from Japan.
(*Photo by Oliver G. Irons, London.*)

good mica down to a considerable depth, but the mining can often not be continued until the mica content is exhausted, as the costs for raising the material and for pumping increase to such a degree

that the mining operations become uneconomical. A few mines, however, which work with modern plant are a remarkable exception to this rule, as, for example, the Lacey mine in Canada, the workings of which have already reached a depth of 185 feet. This mine has two shafts, a main shaft and a ventilating shaft. The bottom of the first level lies at a depth of 52 feet, and there are five further levels at intervals of 22 feet, connected with each other by ladders. Of these levels the fourth, with a length of 215 feet, is the most extensive. At the mouth of the pit there is a winding plant, after the style of a derrick, worked by a steam winch. The extracted rock as well as the plates of mica are drawn up in flat open wooden boxes, which hang by three chains and have each a capacity of 15 cwt. The rock drills are worked by steam or compressed air. A Cameron pump is employed for lifting the water of the mine. For providing steam for the winches, compressors and pumps, two boilers, one of 70 h.p. and the other of 30 h.p., are installed. The number of men employed varies between 35 and 60. The Lacey mine is one of the deepest; most reach a depth of less than 50 yards, while very few go deeper.

The mining of mica in India is generally carried out in a most primitive manner. In Bengal, mines are only worked during the hottest part of the year, between November and May, that is, during the time when there is little agricultural work. This is owing to the two reasons that the men who work in the mines are the same as those who work on the land, and that the mines are flooded during the cool rainy season.

The fact that water has done the preliminary work, and exposed the rock in many cases, makes it much easier to discover the veins of mica. When a system of veins is discovered, open cuttings are made at suitable places, and the rock is excavated until the walls, which are in no way supported, threaten to fall in, or actually fall in, and bury a number of men. Generally the material is excavated only to the depth to which the rock is broken up by the action of water, &c., so that it is rarely necessary

to call in the aid of explosives. Indeed, it is obvious that the disintegration of feldspar in such a moist hot climate as that of India must proceed at an extraordinarily rapid rate during the rainy season. The mining of sound rock can only be undertaken with commercial advantage when there is a very large mica content.

The mining is carried out by coolies and their families. The digging out of the mica slabs is done by the men, while the women carry out the rock and mica and deal with the water. Thus all is done without machinery, winding apparatus, or pumps. The women arrange themselves in a long row and pass the rock and mica in baskets from hand to hand, while the water is passed in water vessels in the same way. It is obvious that with such methods the wages must be extraordinarily low. The men receive about $2\frac{1}{4}d.$ and the women rather less than $1\frac{1}{4}d.$ a day.

In some cases, where the mines are from 100 to 150 feet deep, winding and pumping apparatus is employed. Thus, in Madras, the deposits are of such a nature that the mineowner is compelled to employ modern methods. Fig. 17 illustrates particularly the methods adopted in Bengal.

Many mines in Canada are also worked periodically, as the labour employed is recruited from agricultural labour. As most of the work on the farms in Canada is done during the warm period of the year, most of the mining work is done in winter. The transport of the material is also easier in winter, as it can be carried on sleighs to the railway stations, which often lie at great distances from the mines. Modern methods are already employed to a large extent in Canada. The steam drill is employed in numerous large mines, but the hand-drill is still used in the smaller ones. In 1905 there were between 500 and 700 men employed in Canadian mines, while the number employed in 1908 in Indian mines was more than 15,000.

The mines of the United States, particularly those in New Hampshire, are largely surface workings. Here also the machine drill is being more and more

employed, in spite of the obstinate resistance of short-sighted workmen, as it results in a saving of 50 per cent. in operating costs. The pegmatite veins and branches containing the mica are generally found covered with large masses of rock which must first be excavated. There is still much rock which has to be extracted, and this considerably increases the cost of working. The mines of North Carolina yield a first-class glazing mica which, however, is rather costly, and cannot compete with imported mica. A comparatively large proportion of the mica produced in New Hampshire is in small pieces, which are employed chiefly for electrical purposes.

Before the mica is ready for export it must be dressed. This is carried out in different manners, according to the place of origin and the purpose for which it is to be employed. In Canada the dressing is carried out as follows: After blasting, the mica blocks are separated from the pieces of rock and undergo a process of selection. Those which appear to be of value are shaped by cleaving, and the others are thrown away. The shaped plates are then cleaned, sorted, and packed in barrels in quantities of from 325 to 350 lbs., which are weighed before they leave the mines. A further dressing is given in the mica cutting works in Ottawa, to which the raw mica is sent by boat. Here the plates are thoroughly and carefully sorted, split into plates of about $\frac{1}{8}$ inch thick, cleaned from small pieces of adhering rock, and all inclusions are eliminated. They are then sorted according to quality. The pieces then pass into the hands of the "scriber," who marks on each plate how it shall be cut. The "cutter" cuts through the plates according to these instructions with large shears. At the General Electric Company's factory this operation is carried out by machine shears attended by from 60 to 80 girls. Finally, the pieces are sorted again and again, according to quality and size.

Micanite.

If the mica is to be employed for the manufacture of micanite a further dressing is necessary. The corners of the plates are first carefully rubbed down

with sandpaper, and they are then split repeatedly until they have a thickness of about one-thousandth of an inch. These thin plates are then again sorted, and bad pieces are eliminated. Through all these processes the principle of the division of labour is followed to a large extent, so that each piece of mica has to pass through many hands. Finally, the mica is packed in boxes.

Of the total amount of mica extracted from the mine only from 2 per cent. to 5 per cent. is actually used commercially. All the rest is wasted. It is not surprising, therefore, that the mine-owners are making every effort to realise the value of this large quantity of waste mica in order to raise the economy of production. Their efforts have, to a certain extent, been successful, as, within recent years, scales of mica which are too small for direct commercial application are employed in the manufacture of micanite, mica mats, and mica powder.

The manufacture of micanite is an American invention. The first process was originated by C. W. Jefferson and A. H. S. Dyer in 1892. The manufacture of compressed micanite for commutators is carried out in the following manner : the finely split mica scales are laid out over a large table in such a manner that they just overlap, leaving no spaces between. When such a layer is completed a strongly insulating binding material is spread over it, and then a second layer is laid out in such a manner that the joints in the lower layer are covered by whole pieces. Several layers are made up in this way until a plate of the required thickness is produced. The plate is then put into a large steam-heated hydraulic press, and subjected to a very great pressure. This stage of the manufacture is particularly important, as the quality of the micanite depends to a very large degree upon the temperature and pressure employed. The varnish or binding material is almost entirely pressed out of the micanite during this operation, so that the finished plates contain not more than 1 per cent. or 2 per cent. of binding material. After cooling, the plates are planed smooth and to an equal thickness. The variation from the required thickness must not be

more than 0·025 of a millimetre, and the accuracy of this measurement is controlled by specially constructed instruments.

Plates of micanite which are required to be flexible are manufactured with a non-drying varnish, and with as thin mica scales as is possible. A particular variety, which is flexible on being warmed, and can, therefore, be formed into any required shape, retaining this shape when cool, is produced by employing a large quantity of varnish and reducing the pressure, so that the varnish is not expelled.

Micanite paper and micanite linen are manufactured by sticking very thin soft scales of mica on paper or linen with the aid of an elastic and good adhesive varnish. In all cases, of course, a varnish which does not in any way attack copper must be chosen. Generally, this varnish is made up by the micanite works themselves.

Investigations into the technical qualities of the various mica products, particularly micanite, have been made by the National Physical Laboratory and the firms of Messrs. Crompton & Co. and Messrs. Siemens Bros. Experiments to determine breakdown pressure were made between brass electrodes of 1 inch diameter and with alternating current at 50 cycles. The results given in the accompanying table are the averages of a number of experiments. The mechanical strength of the material was determined by means of a kind of punch die which had a circumference of ½ inch. The pressure on the punch was rapidly increased until the material was pierced through. The flexibility was tested by bending pieces round cylinders of various diameters until they broke or showed distinct signs of fracture. Finally, to determine the influence of heat, the pieces, before being tested, were placed in an electrically-heated oven for a long time and kept at a constant temperature. In the accompanying table "A" denotes "not heated," "B" denotes "heated to a temperature of from 75° to 100° C.," "C" 100° to 125° C., "D" "125° to 150° C." The heating was not continuous, but was kept up regularly during working hours. The results are shown in the following tables :—

	Mica linen.	Mica paper.
Average breakdown pressure in volts	A 2,826 B 3,383 C 3,618 D 3,288	2,403 2,875 3,500 2,840
Thickness in mm.	0·230	0·125
Volts per mm.	A 12,300 B 14,700 C 15,700 D 14,300	19,300 23,000 28,000 22,700
Shear strength in pounds ...	A 27 00 B 36·80 C 30·00 D 30 80	33·20 39·00 33·30 33·40
Flexibility (diameter of smallest cylinder in mm.) ...	A 1.6 B 1·6 C 3·2 D 250·0	1·6 1 6 1·6 1·6

Behaviour of Mica after Constant Heating.

Length of heating period.	Temperature.	Thickness in mm.	Volts per mm.	Breaking load in pounds.
1 Month ...	A	0·559	25,045	222 0
	B	0·508	21,660	177·0
	C	0·635	25,204	298·0
	D	0·635	25,995	265·0
6 Months ...	A	0·610	31,188	234·0
	B	0 483	35,206	148·0
	C	0 635	31,500	197·0
	D	0·635	29,928	257 0
9 Months ...	A	0·711	25,320	365·0
	B	0·483	29,010	245·0
	C	0·635	23,630	263·0
	D	0·483	37,300	181·0
12 Months ...	A	0·457	30,600	137·0
	B	0 584	22,250	260·0
	C	0·610	21,300	203·0
	D	0·610	22,960	140·0

Besides mica, many other kinds of insulating materials were tested in the same way. As a result it was found that besides asbestos and ohmulit, only mica could withstand a temperature of 125° C. for twelve months without being damaged.

EXPERIMENTS BY HOLITSCHER.

Test.	Breakdown pressure in volts.		
	Cold.	Hot.	
		Bent.	Flat.
A	25,000	25,000	23,000
B	25,000	22,500	20,000
C	24,000	23,000	23,000

Mica Mats.

The process for the manufacture of mica mats has been mainly developed by the Mica Boiler Covering Company, an Anglo-Canadian Company. The mica waste used for this purpose is passed through ribbed rollers in order to loosen the scales of the pieces of mica, which are then separated by means of a powerful air blast. The scales are then arranged in layers of suitable thickness, and passed between lightly galvanised wire netting, to which they are sewn with wire by means of a special machine. In this manner a flexible web of mica is produced, and this is covered on one side with stiff linen, and on the other with paper, and finished off to the desired shape. Finally, the edges of the coverings are firmly bound up together. On account of its high flexibility, amber mica is generally employed for this purpose. In 1897, 140 tons of mica were consumed by the Company, producing mats to the value of £500.

Mica Powder.

In the manufacture of mica powder considerable difficulty is experienced on account of the properties of the mineral. Thus, it is not possible to pulverise mica in the ordinary manner, as sufficient friction cannot be produced either between the slippery scales themselves or between the scales and the grinding stone. This difficulty, however, was overcome by the construction of special machinery. The apparatus mainly in use at present is a disintegrator consisting principally of a large metal cylinder containing a large number of metal balls. The cylinder revolves at a speed of between 2,000 and 3,000 revolutions per minute. The powder produced by the hammering action of the balls either falls through a sieve or is drawn out through the sieve by an exhauster, and only particles of a predetermined size can come out. The powder is then drawn into a container from which the air escapes, leaving the mica powder behind. Different qualities of powder are produced by employing sieves of varying mesh.

The chief works of the mica powder industry are in the United States and Canada. As the cost of pulverised mica is small, the possibility of its application depends entirely on the cost of transport.

APPLICATIONS.

While mica is only employed in large quantities for a very few purposes, its applications are remarkably varied, and it is of considerable interest to discuss some of these applications which, while of no commercial importance, may be of interest for other reasons.

By far the largest quantity of mica is at the present time employed for insulation purposes in the electrical industry. Pure mica is employed for the insulation of commutators of small dynamos and motors. The little plates of mica for this purpose should have a thickness of from 0·6 to 1 millimetre, and must be as soft, or softer, than copper, as the mica has to be turned down together with the copper segments. Amber mica is therefore particularly suitable, but, on account of the high cost of this species, the green muscovite variety obtained from India is largely employed. Pure mica has, however, recently been largely superseded in heavy electrical work by an artificial mica or micanite. The manufacture of the latter has already been discussed in the previous chapter (page 60). For large electrical machines only micanite can be used, as plates of the required dimensions could hardly be obtained, and, in any event, would be much too costly. Micanite is not, however, only employed on account of this fact. It has also the advantage that it can be made up into any desired shape and is free from certain faults which often occur in natural plates. Pure mica is rarely homogeneous, as the plates are often thicker in some places than others, and also often vary in

hardness. Inclusions of foreign bodies are also frequent, such as an iron oxide, which conducts electricity, and, therefore, destroys the insulating property. The adhesion of the laminæ of good micanite is also better than that of natural mica.

On account of the perfection in the methods of producing commutator micanite (white micanite), the sweating of varnish from the micanite which sometimes causes trouble has been prevented. Finally, the objection that micanite is attacked by oil is an ineffective argument against micanite, as natural mica is also completely destroyed by oil. For high-speed electrical machinery, particularly turbo-generators, the so-called "turbomic," a very soft variety of micanite, is employed, and is found to be a good substitute for the costly soft varieties of mica.

The extended application of micanite has made it possible for the mine-owners to sell also the small pieces of mica which could formerly not be put on the market. Many mines have been resuscitated since the realisation of the value of the waste product.

Mica is employed also as an insulating material for all kinds of electrical apparatus; for example, for the insulation of terminals from their bases, in thermo-cells for the separation of the elements, for the support of the wires in bolometers, for resistances, and for the insulation between the primary and secondary windings of induction coils. It is also used as an insulating medium between the plates of condensers.

Mica is also largely employed in the heating apparatus manufactured by the Prometheus and several other companies. The heating elements consist of strips of mica to which is attached as a heating resistance a very thin film of silver. Any desired combination of these silvered strips of mica can be connected up together, and on account of the flexibility of the mica they can be arranged to suit the shape of the heating apparatus.

As already pointed out, the specific gravity of mica is by no means small. It is possible, however, owing to the extraordinary cleavage properties of the

mineral, to obtain scales of very minute weight, which are at the same time comparatively strong and are not easily broken. As a consequence of this, strips of mica are employed in the manufacture of

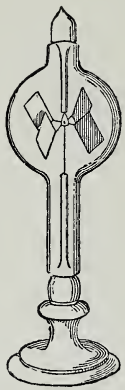

Fig. 19.—Radiometer.

many scientific instruments. The so-called light mill or radiometer (Fig. 19) is an apparatus to show the existence of heat rays. It consists of an exhausted glass vessel with a vertical metal pin on which is pivoted a four-armed wire cross with very thin annealed mica veins. Each of these veins is

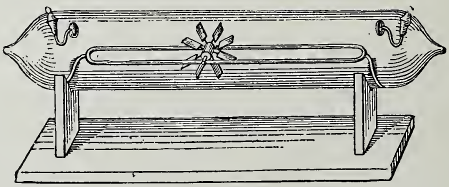

Fig. 20.—Crookes' Tube with movable Paddle-wheel.

blackened on one side, so that the black surfaces all face in the same direction. If light or heat rays are allowed to fall on this light mill, it will begin to revolve more or less rapidly, the unblackened surfaces going forward.

A similarly exhausted tube is shown in Fig. 20.

This also contains a little wheel with mica wings, which in this case can run along glass rails. If the electrodes shown in the upper corners right, and left, are connected with a powerful induction coil, the wheel is moved forward by cathode rays.

The use of a thin mica sheet for compass cards is a comparatively early application. As the sensitiveness of a compass is the greater, the less the weight and friction of the card, all care must be extended in the construction of a compass to reduce these

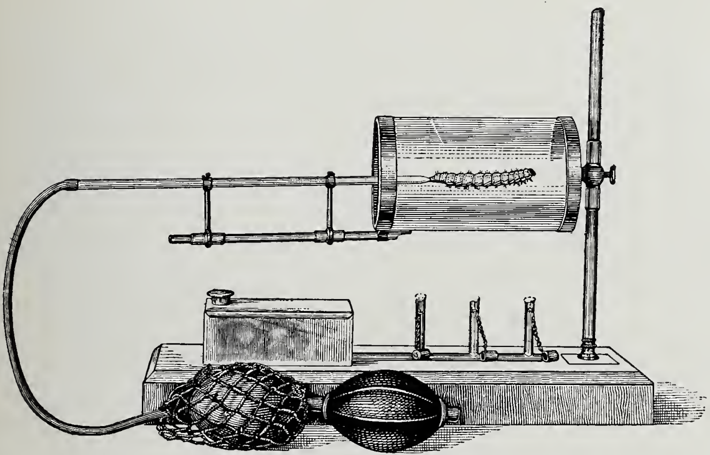

Fig. 21.—Heater for Drying Caterpillar Skins.

(*From Lamperl's "Grossschmetterlinge und Raupen Mitteleuropas."*)

unfavourable influences. On this account it is usual either to float the card in a fluid or to employ a material which is strong enough to carry the magnets, and which has a large enough surface coupled with a very light weight. Such a material is mica. The standard compass of the Imperial German Navy has two cards of mica pasted over with paper. Four double-laminated magnets are attached to each. The boats compass of the German Navy is similar, but smaller. Both are used for very fine magnetic measurements. For navigation purposes a fluid compass is generally employed.

The resistance of mica to the effects of high temperatures, and its capability of withstanding rapid changes of temperature, make it a suitable substitute for glass, in cases where the latter would easily crack. The consumption of mica for lamp chimneys has fallen considerably, due to the modern manufacture of refractory kinds of glass, but has by no means ceased. It is universally employed for the so-called micro-burners used for heating thermostats, also for lamp chimney caps. Considerable quantities of mica are used for the fronts of anthracite stoves. The heat-resisting qualities of mica are also made use of in many kinds of scientific apparatus. Fig. 20 shows a preparing stove for caterpillars. It is used for the purpose of drying skins of caterpillars, at the same time retaining their natural shape. This is done by drawing the skin over a straw and distending it by blowing air into it. At the same time the rotatable mica cylinder in which the caterpillar is fixed is heated by a lamp, and a complete, uniform, and quick drying is obtained.

It is essential that the combustion in blast furnaces, boiler and other furnaces should be continuously observed, and it is usual, therefore, to supply spy holes in the furnace doors through which one can look at the fire. These holes are closed with sheets of mica which, besides resisting the heat, have the further property of being only very slightly attacked by the gases of combustion, and by being opaque to a high degree to the intense heat rays coming from the fire.

This last characteristic makes mica of particular value for protective spectacles. These are useful not only to protect the eyes from heat rays from furnaces of all kinds, but also from foreign bodies which might fly into the eyes, and from dust, smoke, and poisonous or chemically active gases. Mica "glasses" are, therefore, largely employed in quarries, glass works, grinding shops, in mines, chemical factories, gas works, and also by bee-keepers. The advantage of mica, as compared with glass, are particularly emphasised in such cases. It is thus of particular value to the workman, that mica glasses are practically

unbreakable and that if they are by any chance broken there are no harmful splinters. To these advantages must be aded the light weight of the mica glasses, the fact that they are not clouded over by condensed moisture in winter, and that they are easily cut or bent to any particular form. For some purposes protective glasses are not sufficient, as, for example, when it is necessary to have a protective helmet which shuts off the entire head in an airtight

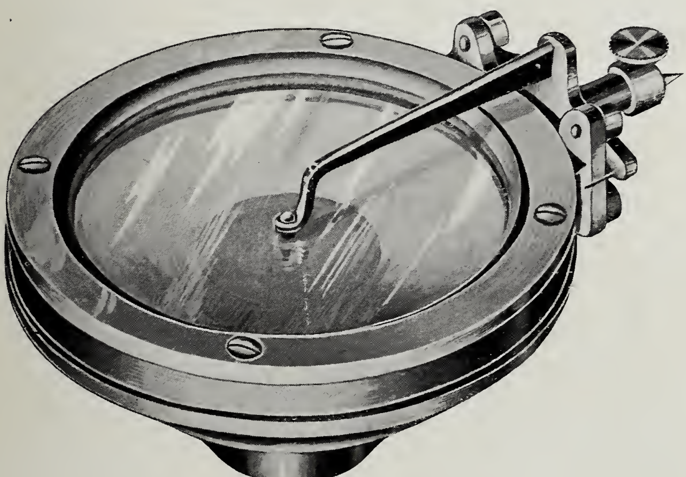

Fig. 22.—Gramophone Sound-box with Mica Diaphragm.

compartment, and, of course, is connected with some form of breathing apparatus. For such helmets a large sheet of mica is generally employed, so as not to interfere with the sight in any way, in spite of its comparatively great distance from the eyes. Such helmets are employed as smoke helmets by firemen, and as dust helmets in many technical processes. Further, they are almost universally employed in mines where the rescue parties have to enter the pit when it is full of poisonous gases.

Its high opaqueness to heat rays makes mica particularly suitable for other purposes. Thus, the con-

densing lens of projection apparatus is subject to severe heat from the source of light, which may result in the destruction of the lens, and so it is usual to protect it by an intermediate plate of mica, or a vessel of water.

In India cheap mica waste is employed as a protection against the intense radiant heat of the tropical sun, for stuffing helmets, portions of clothing, vehicle hoods, etc. It has also been employed under roofs with good results. Thus a layer of mica about 9 inches thick should effect a reduction of temperature of 15° C. immediately under a roof.

The heat conductivity of mica is also very low. Indeed, there is perhaps no such durable material which can compare with it. It is employed, therefore, where it can be obtained cheaply, for the insulation of ice machines and ice chambers, and particularly for steam boilers and steam pipes, partly in the form of powder and partly in the form of mica mats. The locomotives of most railways in the United States and Canada have mica lagging.

It is perhaps of interest to include the results of experiments which have been made on the heat insulating property of mica. R. Atkinson, the Chief Engineer of the Canadian Pacific Railway, determined the heat losses of some large steam boilers of equal sizes, insulated with different materials. The results are given in the following table :—

Nature of lagging.	Drop in temperature in 5 hours.	Temperature at end of 5 hours.
Boiler without lagging... ...	84 deg.	128° C.
Asbestos mixture	53 deg.	159° C.
Magnesia blocks...	$33\frac{3}{4}$ deg.	$178\frac{1}{4}$° C.
Wood with air space between...	$33\frac{3}{4}$ deg.	$178\frac{1}{4}$° C.
Asbestos and wood	30 deg.	181° C.
Mica	20 deg.	192° C.

According to experiments by Professor Capper, the loss by condensation over a given surface of steam piping was 1·516 lbs. of steam in the case of pipes

without lagging, and 0·177 lbs. of steam with mica lagging.

The loss of heat and pressure in a boiler during the first hour of cooling was also measured, with the following result :—

Nature of lagging.	Loss of pressure in 1 hour in lbs. per square inch.	Loss of heat in heat units.*
Uninsulated boiler	56	231,000
Wood and asbestos paper ...	20	73,500
Magnesia blocks	13	43,900
Mica insulation	6	21,400
Kieselguhr	24	77,900

* The quantity of water in the boiler was 7,000 lbs.

Mica is also employed as a lubricant for axles under great pressure. It is pulverised only with difficulty; indeed, one might say it cannot be pulverised, as the so-called mica powder consists not of minute spherical particles, but always of minute scales which are wide in comparison with their thickness. In consequence of the smooth surfaces of these scales, they slip easily one over the other with only slight friction, and it is this fact which gives mica powder its friction-reducing property. Mixed with machine grease it has almost the excellent lubricating properties of graphite.

The fact that mica scales will take colouring matter, and the glittering effect with reflected light, make them suitable for the manufacture of glistening wall papers, postcards, and artificial flowers. The consumption for this purpose, however, is small at present, as is also the consumption for the manufacture of coloured brocade, which principally depends upon the prevailing fashion. Brocade is only manufactured by a few works in Germany. One process consists in crushing and grinding the mica and then colouring it with analine dyes in various shades. Before applying mica, the material is painted with an oil colour of the colour of the brocade, varnished with linseed oil, and then partially dried, and finally

dusted with the coloured powder. When thoroughly dry, the powder not adhering is brushed off with a soft brush.

Mica waste is in large demand in some districts of India. On certain festive occasions, banners, sunshades, clothes, fans, toys and vases are sprinkled with it on account of the glittering effect produced in sunlight. Scenes of local life are painted on thin sheets of mica, and can be purchased in most bazaars (see frontispiece). Many other objects of mica are also sold in India. We have before us a price list of a mica firm in Madras. Besides lanterns, and lampshades, in the greatest variety, there are painted boxes and caskets; indeed, even cabinets of mica, which, though not very durable on account of the softness of the material, certainly offer good protection against the attack of insects; and there are many other uses, such as dishes for food, fruit dishes, bowls and tea services, butter dishes, sauce tureens, plate mats and wine glasses, mostly highly painted, and in shades which are somewhat painful to the eyes of the cultured European.

As in the case of many natural products which exhibit peculiar properties, mica is also employed amongst some peoples for medical purposes, not only in India but in China. Raja Sir Sourindro Mohan Tagore gives a list of 224 medicines in which mica is one of the chief constituents. One prescription runs as follows: "Take a pound of mica and add thereto cow's milk, buffalo's milk, and goat's milk, gangapatra, human urine, leaves of the Vata tree and goat's blood. The effect would be a hundred times better if the mica took on a ruby colour during heating. If mica burnt in such a way is taken as a tonic it increases the beauty of the complexion, strengthens the body, prevents early death, and is a preventative against the weakness of old age and all illnesses."

On account of the ease with which mica plates are split into thin laminæ and cut with scissors, and their comparative strength, they are particularly suitable for cover "glasses" for microscope slides. For this purpose it is found best to split the plates

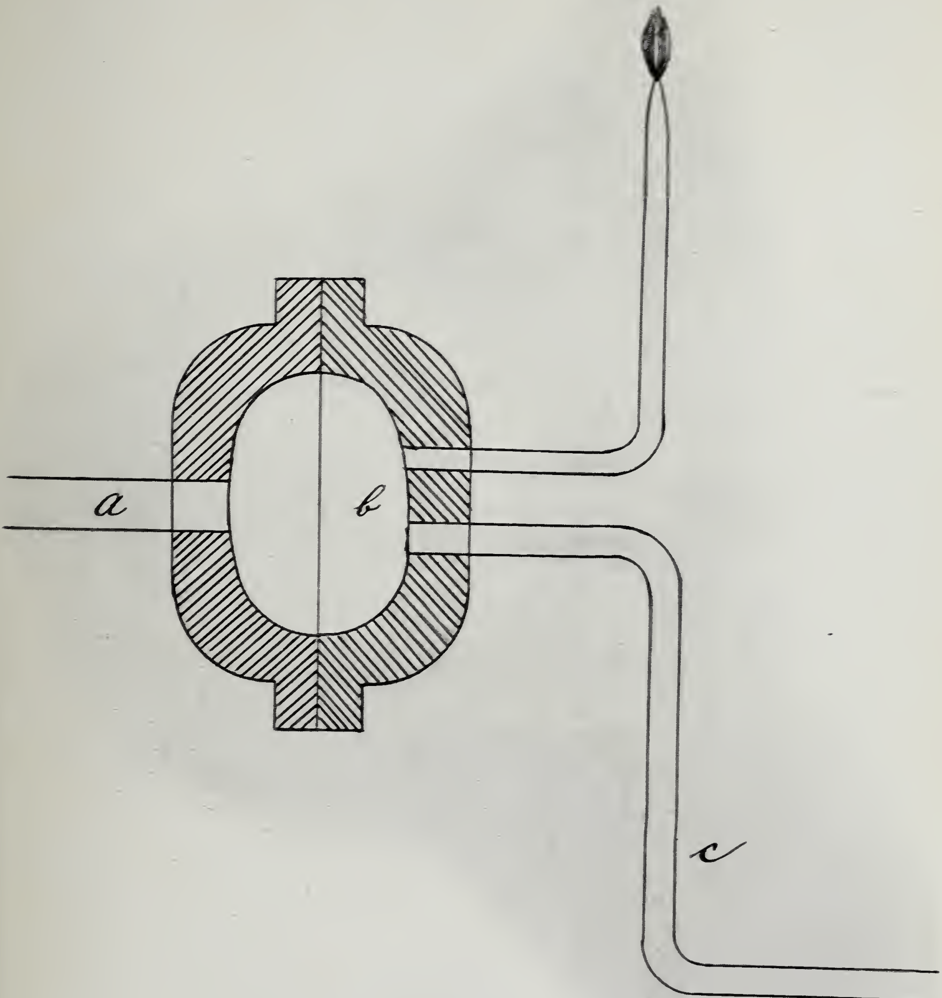

Fig. 23.—Gas-flame Manometer with Mica Diaphragm.

under water until the correct thickness is obtained, and then to cut them to the desired form with scissors. The use of mica for this purpose has been found particularly convenient in the case of series of sections. Plates of mica for holding zoological preparations which are to be preserved in spirit are prepared in the same way. These plates have this great advantage over glass, that they can be pierced with a needle in order to fix the preparation to them.

As mica is practically unbreakable, it is used for making photographic plates and films for explorers. Mirrors have also been made of mica, and silvered plates which can be bent into different forms have been used as reflectors. Mica window panes are still employed in many places even to-day, for example, in the State of Goyaz, Brazil, where the mineral occurs in very large blocks.* Mica windows are, it appears, also in use amongst the Pueblo Indians in Arizona and also in Peru and Siberia. They are also in use in Europe in powder factories, on the ground that they will not do harm to the workers should they be broken by an explosion. Hexagonal collapsible lanterns with mica panes are in use in the Italian and French Armies.

Mica is absolutely indispensable for many crystallographic experiments with the polarization microscope. For this purpose very fine laminæ, called quarter-wave plates, which have an exact and definite thickness, are employed. These serve to distinguish between mono-axial and bi-axial crystals, as well as to determine the character of chromatic polarization and the properties of doubly refracting bi-axial crystals. We cannot here go further into this sphere of application. Further particulars may be found, for example, in Groth's "Physikalische Krystallographie," 1905, page 138, etc.

Finally, the elasticity of mica makes it particularly suitable for the reception of sound waves. When one speaks into a gramophone the sound waves are taken up by the trumpet, and pass through a connecting tube into the sounding box (Fig. 22). This is a flat

* According to the personal statement of Herr Prof. Dr. Ehrenreich, Berlin.

Fig 24.—"Mica book" from the Argentine.

cylindrical case open on the side connecting with the trumpet, and closed on the opposite side by a diaphragm of mica or glass. This diaphragm is set in vigorous vibration by the sound waves, and the oscillations are transferred to the inscribing needle by means of a lever. The diaphragm is made of a hard mica, so hard that it gives a clear, almost metallic, sound when it is let fall on to something solid.

Mica discs are also employed in the gas-flame manometer (Fig. 23), the instrument usually employed for any acoustic investigations. If tube "A" shown in the illustration is connected with a room, and a sound made in that room, alternate compression and rarefaction of the air takes place in the tube. The diaphragm is bent towards the tube "A" at each rarefaction, and towards "B" at each compression. The flame makes corresponding movements, becoming alternately smaller and larger, the frequency of the alternations depending on the pitch note; for example, 435 times a second for A′. These rapid movements of the flame are observed by means of a rotating mirror.

Mica has been successfully employed in Madras, in the manufacture of artificial stones, this being effected by the compression of mica waste with some binding agent.

A kind of dynamite is manufactured by saturating mica powder with nitro-glycerine.

Mica is also employed with good results as an artificial manure. As, however, mica is not at all easily disintegrated, the action can only be a mechanical one, consisting possibly of loosening of the soil.

APPENDIX.

Tables of Production and Consumption of Mica.

Tables of Production and Consumption of Mica.

VALUE OF MICA PRODUCED IN INDIA, CANADA, UNITED STATES, AND GERMAN EAST AFRICA, IN POUNDS STERLING.

Year.	India.	Canada.	United States.	German East Africa.	Total.
1894	42,516	9,359	10,757	—	62,632
1895	71,481	13,347	11,464	—	96,292
1896	76,891	12,320	13,796	—	103,007
1897	71,238	15,605	19,553	—	106,396
1898	53,890	24,306	26,919	—	105,115
1899	73,372	33,470	24,941	—	131,783
1900	109,554	34,086	30,381	—	174,021
1901	70,034	32,854	24,348	—	127,236
1902	87,594	27,906	24,404	—	139,904
1903	86,297	36,520	29,389	294	152,500
1904	97,932	33,013	24,705	840	156,490
1905	159,627	36,598	36,671	1,808	234,704
1906	254,999	62,405	56,466	3,350	377,220
1907	228,161	64,188	80,515	—	372,864
1908	126,834	28,720	55,015	10,291	220,860
1909	38,157	30,345	51,296	12,624	132,422
1910	54,427	29,447	69,219	15,645	168,738

VALUE OF EXPORTED MICA IN POUNDS STERLING.

Year.	India.	Canada.	German East Africa.
1904	89,000	41,200	301
1905	98,800	37,200	858
1906	161,400	121,000	1,848
1907 ...	258,000	87,500	3,420
1908	230,400	41,200	—
1909	—	53,300	10,500
1910	—	68,800	13,200

MICA EXPORTED FROM GERMAN EAST AFRICA SINCE 1903.*

Year.	Total export in cwt.	Value in pounds sterling.	Average value per cwt.
			£
1903–04	95·4	301	—
1904–05	169·2	861	—
1905–06	244·6	1,853	—
1906–07	478·3	3,434	7·18
1907–08	469·2	3,401	7·25
1908–09	1550·6	10,548	6·81
1909–10	1897·0	12,940	6·83
1910–11	2131·6	16,036	7·53

* Practically all exported to Germany.

PRODUCTION AND EXPORT OF INDIA.

Year.	Production. Cwts.	Export. Cwts.	Place of origin.	Value. £	Weight. Cwts.
1904	22,164	21,548	Bengal	67,802	18,001
			Bombay	374	217
			Madras	18,121	3,330
1905	25,641	19,575	Bengal	59,187	13,167
			Bombay	132	74
			Madras	38,613	6,334
1906	52,543	31,554	Bengal	107,904	21,568
			Bombay	1,221	198
			Madras	50,502	9,788
1907	52,203	51,426	Bengal	191,812	35,496
			Bombay	2,384	634
			Madras	60,802	15,296
1908	53,543	28,922	Bengal	169,810	25,374
			Bombay	2,862	710
			Madras	55,476	12,833

DISTRIBUTION OF MICA EXPORTED FROM INDIA.

AVERAGE VALUES FOR THE YEARS FROM 1904 TO 1908.

Country to which exported	Average quantities.		Average value.		Value per cwt. £
	Cwts.	Percentage of total export.	£	Percentage of total export.	
England ...	17,226	52·8	102,307	61·9	5·94
United States ...	4,781	14·7	29,497	17·8	6·17
Germany ...	7,391	22·7	21,337	12·9	2·89
Belgium ...	1,050	3·2	3,551	2·1	3·38
France	558	1·7	2,497	1·5	4·47
Other countries..	1,599	4·9	6,214	3·8	3·89

PRODUCTION AND EXPORT OF CANADA SINCE 1891.

Year.	Production. Value in £	Export. Value in £	Year.	Production. Value in £.	Export. Value in £.
1891	14,850	7,790	1901	33,200	31,700
1892	21,720	17,950	1902	28,200	81,400
1893	15,700	14,750	1903	36,900	40,700
1894	9,470	8,100	1904	33,350	41,200
1895	13,500	10,100	1905	37,000	37,200
1896	12,450	9,900	1906	63,200	120,800
1897	15,800	14,350	1907	65,000	87,500
1898	24,600	22,950	1908	29,000	41,250
1899	33,800	31,800	1909	30,700	53,400
1900	34,500	30,400	1910	29,800	68,700

DISTRIBUTION OF THE CANADIAN EXPORT.

1906—1910.

(A) VALUE IN POUNDS STERLING.

Year	United States.	%	Great Britain.	%	Other countries	%	Total.
1906	107,800	89·3	12,200	10·1	768	0·6	120,768
1907	77,400	88·3	9,110	10·4	1,135	1·3	87,645
1908	23,900	57·8	16,850	40·8	578	1·4	40,518
1909	47,700	89·4	5,050	9·5	588	1·1	53,338
1910	60,500	88·1	7,830	11·4	329	0·5	65,659

(B) QUANTITY IN CWTS.

Year.	United States.	%	Great Britain.	%	Other countries	%	Total.
1906	13,127	80·6	2,988	18·3	173	1·1	16,288
1907	8,358	83·8	1,432	14·4	183	1·8	9,973
1908	2,360	45·6	2,773	53·5	47	0·9	5,180
1909	5,795	90·5	549	8·6	58	0·9	6,402
1910	6,746	80·6	1,546	18·5	76	0·9	8,368

PRODUCTION OF THE UNITED STATES FROM 1897—1910.*

VALUE IN DOLLARS.

Year.	Mica Plates.	Broken Mica.	Total.	Year.	Mica Plates.	Broken Mica.	Total.
1897	80,774	14,452	95,226	1904	109,462	10,854	120,316
1898	103,534	27,564	131.098	1905	160,732	17,856	178,588
1899	70,587	50,878	121,405	1906	252,248	22,742	274,990
1900	92,758	55,202	147,960	1907	349,311	42,800	392,111
1901	98,859	19,719	118,578	1908	234,021	33,904	267,925
1902	83,843	35,006	118,849	1909	234,482	46,047	280,529
1903	118,088	25,040	143,128	1910	283,832	53,265	337,097

* No mica is exported from the United States.

IMPORTS OF MICA TO THE UNITED STATES FROM 1906—1910.

Year.	Raw.		Cut or split.		Total.	
	Quantity in lbs.	Value in $.	Quantity in lbs.	Value in $.	Quantity in lbs.	Value in $.
1906	2,984,719	983,981	82,019	58,627	3,066,738	1,042,608
1907	2,226,460	848,098	112,230	77,161	2,338,690	925,259
1908	497,332	224,456	51,041	41,602	548,373	266,058
1909	1,678,482	533,218	168,169	85,595	1,846,651	618,813
1910	1,424,618	460,694	536,905	263,831	1,961,523	724,525

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